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ON

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VOL. II.—1865.

EDITED BY

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PREFACE TO VOL. II.

I HAVE to congratulate the Subscribers to these Papers on the successful completion of the Second Volume, and to thank the Contributors who have so willingly and gratuitously aided me. Without being over sanguine, there is I think a fair promise of the series being creditably carried on, at least for the present. Any suggestions for improvement from Subscribers will be gladly welcomed.

The number of original contributions received has been quite as many as I could reasonably expect. The other Papers have been chiefly abridged or adapted from Government Reports, or from books not generally accessible; and I have been guided by my own judgment of their probable utility and interest to the majority of Subscribers. To the P. W. Secretariats of India, the N. W. Provinces and the Punjab, I am indebted for assistance in this matter. From the Madras, Bombay, and Calcutta offices, I regret to say I have as yet received nothing, though many works of great interest are in active progress under those Governments. It is, however, to individual Officers, Civil and Military, of the P. W. Department, and other members of the Profession, especially the Railway Engineers, that I look for aid; and judging from the past two years, I am sure I shall not look in vain.

Several enquiries having been made for particular Papers, an extra number of copies will in future be printed, so that any Paper can be had separately (price 8 As.), and the more interesting of those already issued will be re-printed. Each Contributor will in future be supplied with six copies of his own paper *gratis*, and can have more if desired.

No. X. being the first Quarterly Number of Vol. III., will be issued on 1st February next.

The price for Vol. III. for 1866, will be as before, Rs. 14, if paid by 1st January next; *after* that date, Rs. 16, or Rs. 4 for each Quarterly Number.

Orders and Subscriptions received by the Editor at Roorkee; by Messrs. Thacker and Co., Calcutta or Bombay; or Messrs. Gantz, Brothers, Madras.

English Subscribers will receive their copies through Messrs. Smith, Elder & Co., for 32*s*. the Volume, including postage.

J. G. M.

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LIST OF PLATES.

THE CIVIL ENGINEERING COLLEGES OF INDIA.

THAT several of the earliest and most distinguished Civil Engineers in England were men of little or no education, was for a long time alleged as a proof of the inutility of a scholastic training for the young Civil Engineer. It can scarcely, however, be necessary to refute such an argument now-a-days, nor would it ever have been put forth if the distinction between the theory and practice of any profession had been attended to. A theoretical Engineer is neither more nor less valuable than a theoretical Doctor or Lawyer, and in all three cases the value of a scientific training in the principles of each profession is justly regarded as an indispensable preliminary to the actual practice of it. It is often, however, alleged with a greater show of truth that this preliminary education can be acquired better in Workshops than in a College. Each doubtless has its advantages; the information acquired in the former is more practical, but is necessarily more special; in the latter it covers more ground and is likely to be more generally useful. In England, where the sub-division of labor has been carried to an almost indefinite extent, a man rarely attains eminence in any calling who does not confine himself to some special branch of it, and for the generality of men, even the early training must be special if only from economical considerations. But in a country like India, where the Engineer may have to do the work of half a dozen different men at once, or may constantly have to exchange one kind of work for another, the education required is altogether different, and it may safely be said that, at any rate for the wants of Government, it will best be supplied by a Civil Engineering College.

It is thought, therefore, that some account of those now existing in India will be generally interesting, especially as they are, I believe, the only ones at work in any part of the British Empire.

The Thomason Civil Engineering College, Roorkee, is the oldest in point of date, having been founded in 1847, under the auspices of the Honorable James Thomason, Lieut.-Governor N. W. Provinces. Designed at first chiefly to supply the want of European Overseers and Native Subordinates on the Ganges Canal Works, it was established at Roorkee, in the vicinity of which the most important of those works were then in active progress. Its operations were subsequently much extended and the Course of Study from time to time carefully revised as experience showed what changes were necessary. The general scheme, however, has been little altered from that originally drawn out by Lieut. (now Lieut.-Col. Maclagan) the first Principal, who filled that Office for more than ten years, and to whom the College is mainly indebted for the success it has attained.

The College is divided into the Senior, First, Second, and Third Departments. The Senior consists of Officers of the Army, the First of young Civilians; both of these Departments pursuing the same Course of Study to qualify them for the Public Works or Survey Departments. The Students remain two years, and on the successful completion of their studies receive Certificates and appointments as Assistant Engineers, or Surveyors in the Government service.

The Second Department chiefly consists of English Soldiers, (though there is also a Civilian and Native Class attached,) who remain for one year, and on passing out are appointed Assistant Overseers in the Public Works Department.

The Third Department is entirely for Natives, (the instruction being in the Vernacular,) who remain two years, and are passed out as Sub-Overseers or Sub-Surveyors of the First or Second Class.

All Students have to pass an Entrance Examination: the instruction is gratuitous, and there are certain Scholarships attached to

all three Departments, as well as several handsome prizes—such as The Council's Prize of 1,000 Rs.—The Thomason and Cautley Gold Medals, &c.

The Course of Study varies of course in the different Departments, but includes Mathematics, Civil Engineering, Surveying, and Drawing for all—besides instruction for the higher Departments in Chemistry, Mineralogy, and Photography.

The following is the detail of the four principal subjects for the two higher Departments.

Mathematics.—Arithmetic, Algebra, Geometry, Trigonometry, Statics, Dynamics, Hydro-statics and Hydro-dynamics, Conic Sections, Differential and Integral Calculus, Spherical Trigonometry.

Civil Engineering.—Building Materials, their nature, uses and strength—Principles of General Construction, including Earthwork, Masonry and Carpentry—Special Constructions, such as Roads, Bridges, Buildings, Irrigation Works and Railways—Applied Mechanics—Machinery—Designing—Estimating—Laying out Work.

Surveying.—Use and Adjustment of Instruments, viz.:—Chain, Compass, Sextant, Level and Theodolite, taught practically in the Field—Execution of Surveys with the Chain and Compass, Theodolite and Plane Table—Trigonometrical Surveying—Levelling—Contouring—Practical Astronomy.

Drawing.—Construction of Scales—Making Plans and Sections from actual measurements—Mapping—and a regular course of Engineering, Architectural, Mechanical and Perspective Drawing.

The subjects taught to the two Lower Departments are of course both fewer and are more restricted.

The number of Students now in the College is 114, viz.:—6 Officers, 10 Civilians, 36 Soldiers, and 62 Natives. Since the commencement more than 700 have been qualified for the Public Service in the various Departments, and it may be confidently asserted that they have generally given satisfaction. Indeed, Students bearing the College Certificate are sought after by the Railway Companies and others, having no connexion with the Public Works or Survey Departments, and this extraneous demand

is now so large that Government is obliged to protect its own interests by a guarantee binding the Student not to quit its service within a certain time.

The Staff of the College consists of a Principal and two Assistants (all Engineer Officers), Professors of Experimental Science and of Drawing, Head and Second Masters for the Soldiers, and six Native Masters for the Third Department, besides the Office and Press Establishments, &c.

A view of the College is given in the Frontispiece. The Architect was Capt. Price, now Chief Engineer at Hyderabad. Besides the various Class and Lecture Rooms, the building contains a Library of some 7000 volumes on subjects of general as well as scientific and professional interest, a Drawing Hall, Museums of Geology and of Natural Produce, and a Model Room. To the College are also attached a Press, where Printing, Binding, and Lithography are executed—a Wood Engraving Department—a Depôt for Surveying and Mathematical Instruments—and a Meteorological Observatory.

The Calcutta Civil Engineering College was founded in 1856. Officers and Soldiers do not study here, and there is no Vernacular Department, the majority of the Students being Bengalees, whose instruction is conducted in English. The Course of Study is much the same as that of the First Department of the Thomason College. The general results, however, have not been so good, certainly not from any fault of the instructors, but because the material is inferior, the Bengalee being more fitted for sedentary pursuits than for the active out-door life of a practical Engineer.

*The Madras Civil Engineering College** was formed in 1859, under Captain Winscom, R.E., as Principal, with twenty Military and twenty-six Civil Students.

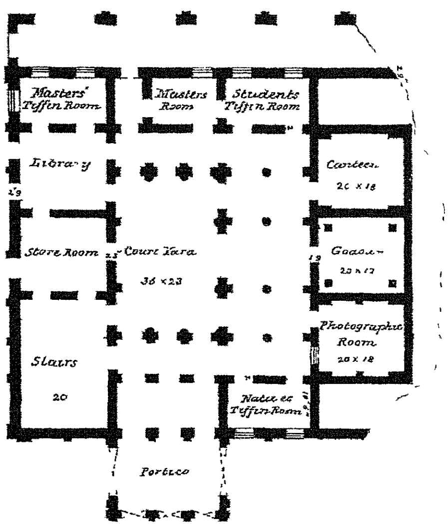
The nucleus for its formation was the Government Survey School, which was established in 1834, for the purpose of training men as Surveyors under the Revenue Department.

In order to supply the wants of the Department Public Works,

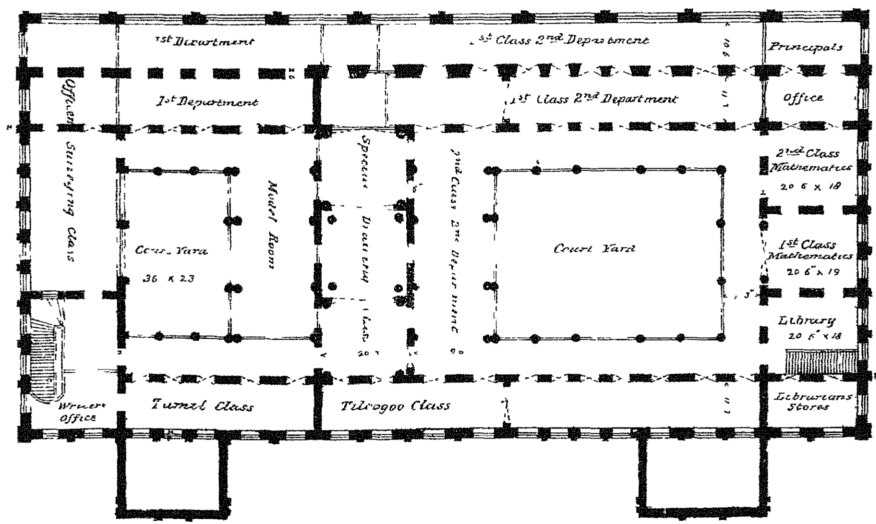
Communicated by Capt. Edgcome, R.E.

MADRAS CIVIL ENGINEERING COLLEGE.

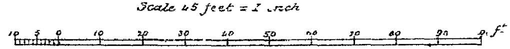
PART OF GROUND PLAN.



UPPER PLAN



Scale 45 feet = 1 inch



the curriculum of instruction was extended, and the Survey School gradually merged into the Civil Engineering College.

As at first established, the College had for its object the training of men as Subordinates only, *i. e.*, Overseers and Sub-Overseers in the Department of Public Works. But in 1861, a special Class for Drawing and Estimating was formed; and in March 1862, a *First Department* was established, for the purpose of training Military Officers and Matriculated Students of the University of Madras for the position of Assistant Engineers. In December 1862, an *Officers' Surveying Class* was attached to the College. So that the Civil Engineering College now consists of a First Department—Officers' Surveying Class—Second Department—Special Survey and Drawing Class.

With an educational Staff of—Principal—Two Assistant Masters for Mathematics—Three Assistant Masters for Surveying, Drawing, and Estimating—Two Assistant Masters for Vernacular Language.

The number of Students has risen from 46 to 103 at close of past Session.

The Course of Instruction, which is similar to that of the Thomason College, extends to about two years, and the average annual out-turn is—Five in First Department—Twenty in Second Department—Fifteen in Draughtsmen, Surveyors, and Estimators.

The building was formerly the Palace of the Nawab of the Carnatic, and though rather an imposing edifice, is not well adapted for a College, as so much space is taken up by the large open courts in the centre of the building.

Captain Winscom, R.E., who was Superintendent of the Government Survey School, was the First Principal of the College.

He was succeeded by Capt. (now Lieut.-Col.) Carpendale, R.E., in 1860, and in November 1863, Capt. Edgcome, R.E., was appointed Principal, and now retains the appointment.

There is also a *Civil Engineering School at Poona*, in the Bombay Presidency, which hitherto has been employed in training Native and European Subordinates only, but is now to be expanded

into a College, towards which a lakh of Rupees has been contributed by Sir Jamsetjee Jeejeebhoy, and for which a very handsome building has been designed, and is now being* erected by Capt. H. St. Clair Wilkins, R.E., who is to be the first Principal.

J. G. M.

No. LI.

ST. MARY MAGDALENE'S CHURCH, MEEAN MEER—PUNJAB.

Designed and Built by the late Captain J. N. Sharp, *Bengal Engineers.*

This handsome Church, designed in the early English style, was built in 1854-56. It is entirely of brick, and the workmanship throughout is of first-rate excellence, and beautifully finished.

The *Outside* is finely plastered with mortar, containing a small admixture of soorkhee, so as to be of a faint reddish tinge, which, with a slate roof, gives a very clean finished look to the exterior. The work is lined in imitation of stone joints. The verandah floors are laid with square blocks of reddish stone, placed diagonally, alternate light and dark stones being used. Stone benches are also provided on the inner side.

Inside, the walls are plastered with mortar made from marble out of the city, from old buildings. This is polished exceedingly smooth and is of a pure white. It is also jointed in imitation of stone. The band running round the chancel and side aisles, shown in the drawings, is made of the same, beautifully finished. The roof trusses are 42 feet span, and are of stained deodar with wrought iron ties; the purlins being covered with boarding of the same wood, on which the slates are laid. The floor is of the same description as the verandahs as a grounding, but the whole of the chancel, and a path 7 feet wide down the centre of the main and side aisles, is of alternate blocks of white marble and a dark agate-like looking stone, which, as well as the marble, is highly polished. These paths are finished off with a neat border inlaid of the same stones. The stones

inside the altar rails have each a *fleur de lis* of the opposite color let into their centre. The steps to the chancel and to the altar are of white marble.

Windows.—The whole of these are filled with stained glass. The ends of the chancel and centre and side aisles have figures in medallion, set in a very rich colored ground, and the side windows are of a black and white diamond and *fleur de lis* pattern, with a colored border, and centres to arched heads.

Font, Altar, &c—The font is of white marble. The Ten Commandments and Lord's Prayer are cut in old English letters, on marble slabs, behind the Communion Table, and colored black and red. The cloth for the table and cushions, &c., is dark green, the former being covered with gilt *fleur de lis.*

Furniture.—Is of stained wood, of a handsome and substantial pattern. The pulpit and reading desk are low, and rather plain.

Gallery.—There is a wooden gallery supported on wooden pillars at the west end.

Lighting.—Consists of bronze brackets with shades for candles, and a bright brass corona over the font.

Punkahs.—Are of green painted sheet iron framed with dark wood, suspended by iron rods from horizontal ones built into the walls. The arrangement is as neat and as little offensive as possible.

Number of Sittings.—There are 32 benches down each side of the centre aisles, with 9 sittings in each; total, 576. The side aisles have 115 each, and the gallery 100, making a total of 906 sittings, but they are too small, and the Church cannot be said to have room for more than 800, or comfortable room for 700 persons.

Cost.—The precise cost is not known, but it is believed to have been about Rs. 90,000, of which Government paid Rs. 43,000, the rest being raised by private subscription.

A. M. B.

No. LII.

JUBBULPORE RAILWAY SPECIFICATIONS.

[*The following extracts are from the Specifications for the works on the E. I. Railway Branch Line, from Allahabad to Jubbulpore,* 221 *miles, now being executed by* MESSRS. WARING AND HUNT, *Contractors; communicated by* H. P. LE MESURIER, ESQ., *Chief Engineer.*]

Earthwork in Embankments and Cuttings.—The embankments will be principally made from side cuttings, either in tanks or trenches, on each side of the line of Railway. It will, however, be necessary in some few places to form the banks from line cuttings, owing to the scarcity of soil alongside of the line. The embanked approaches to level crossings and road diversions to be formed in like manner.

In forming the embankments the earth is to be deposited in layers of such thickness, not less than 2 feet, as the Engineer shall approve, concave in the centre of the embankment; and the embankments are to be raised to such a height above the formation level as may in each case sufficiently allow for subsidence.

To avoid misunderstandings a deduction of one-sixth of the height of all banks will be made, in taking measurements for monthly certificates on account of work executed.

At the discretion of the Engineer, small longitudinal and transverse bunds may be made on the top of banks, to prevent cutting during the rains; these bunds are generally from 9 to 12 inches in height.

Ballast and Road Metalling.—It will consist of hard broken stone, clean gravel, clean kunkur, or hard well-burnt clay, or well-burnt broken bricks, or other approved material of equally good quality.

The ballast is to be broken to such a size as will pass in all directions through a ring $2\frac{1}{2}$ inches in diameter.

The portion of ballast immediately on the formation, at the discretion of the Engineer, may consist of coarsely broken stone or other specified material.

There will be about 158,400 cubic feet of ballast required per mile for a single line, with an additional allowance for sidings and metalling.

Permanent Way.—A single line of railway is to be laid from end to end, with sidings at stations and such other points as the Engineer may direct. The gauge or distance between the rails to be 5 feet 6 inches.

The weight of the permanent way is estimated to be as follows, per mile:—

115 tons rail, of 73 lbs. to the yard.
Maximum length of a rail, 24 feet.
35 tons chairs, 24·5 lbs. each.
5 tons fishes.
3 tons spikes, in cases of about 5 cwts.
$1\frac{1}{4}$ tons bolts and nuts, in cases of about 5 cwts.
$1\frac{1}{2}$ tons of keys, in casks.

The sleepers generally will be of Indian woods, 10 feet long and 12 inches by 6 inches in section, not exceeding 1,700 to the mile, and averaging about 210 tons weight to the mile; but should it be found impossible to obtain a sufficient supply of native sleepers for the line between Allahabad and Myhere, creosoted fir sleepers weighing 142 tons, or Greave's bowl sleepers, weighing 142 tons per mile, will be provided.

The centre line of the railway will be marked out by the Engineers, and stakes driven at proper intervals, giving both the line and level of the rails.

The sleepers are to be prepared for the reception of the chairs by planing the seats for the chairs for the whole breadth of the sleepers, and not less than 18 inches in length for each chair. The surface to be dressed smooth, level, and brought out of winding by means of gauges prepared for that purpose.

The joint sleepers and their chairs are to be first laid down, and the rails fished and laid in their places exactly parallel and level, and to the right gauge. The intermediate chairs having been previously slipped on to the rails, the intermediate sleepers are then to be brought into their proper position, the chairs keyed on to the rails at the exact distance re-

quired, holes bored in the sleepers with the self-adjusting guard auger, and the spikes carefully and firmly driven and fixed.

There will be an average of about 1,700 sleepers laid in every mile of the railway, but plans will be furnished to the contractor shewing their exact distance apart from centre to centre, and other necessary details.

The sleepers and rails are to be laid to the proper height at first, and no raising or lifting through the ballast will be permitted.

In curves such a height is to be given to the outside rail as may be directed by the Engineer, but on the straight parts of the line the rails are to be exactly level across.

All twisted or bent rails must be straightened or brought out of winding by hammering, or by the straightening machine usually employed for that purpose, at the contractor's expense, whether the rails were bent previously to their delivery to him or afterwards.

The price named in the tender for laying the Permanent Way must include the laying of six sets of points and crossings at each station.

If necessary the ends of the rails are to be cut or filed true and square; and, in laying, all the joints must be left wide enough to allow for expansion.

The contractor will be furnished in England with a standard gauge for the width between the rails, and from this all the others required by him are to be made. These will, before being used, be compared with a standard gauge in the possession of the Chief Engineer of the Jubbulpore Railway in India.

The linking-in is not to proceed more in advance of the permanent laying than the Engineer may deem expedient.

Electric Telegraph.—The wire is to be No. 5 gauge of the "best best" annealed galvanized description. The binding and connecting wires are to be of charcoal galvanized iron. The joints of the wires are to be on Ryland's or the best known principle, to be approved by the Company's Consulting Engineer.

There are to be 24 standards to the mile, one of which is to be a straining standard. All are to be made from stout sál spars of the kind known as bullies. Ordinary standards must be 20 feet long, and not less than 5 inches in diameter in any part. The straining standards and those used at stations and road crossings must be not less than 26 feet long, and 6 inches in diameter in the smallest part. The lower ends of all must be charred and buried in the ground not less than 5 feet.

The insulators are to be of the best brown ware, and with their fittings all according to pattern.

The instruments are to be according to pattern; not less than thirty single needle and six Morse printing ones are to be supplied with the usual duplicates.

STONE-WORK. *Ashlar.*—Will be of two kinds—1st, Smooth-faced or tooled ashlar; and 2nd, Fair broached and Rock-faced ashlar, with or without a chisel draft round the edges; the rock-facing where used, not to project more than 2 inches beyond the face of the chisel draft or arris.

It is proposed to use but a limited proportion of this class of work, which will be principally confined to imposts, bed plates for girders, springers, string courses and copings, and occasionally in quoins and walling, and large arches, but power is reserved to use it whenever it may be deemed necessary.

Thickness of Ashlar Courses, and general arrangement.—No course of ashlar to be less than 8 inches thick. One-third of the entire length of each course to be headers. No stone to be less than 2 feet long, and when the thickness of the course does not exceed 10 inches, the stones must not be less than 15 inches on the bed. Where the thickness of the ashlar courses *exceeds* 10 inches, the breadth of the beds wlll not be less than a third more than the thickness of the course.

No header to be of less length than 18 inches in excess of the breadth of the course of ashlar to which it belongs. In walls up to 3 feet thick all headers to be through stones. The beds and joints of all ashlar stones to be dressed perfectly true, square and full. No hollow beds will be allowed.

The vertical joints in all cases to be dressed true and square for at least two-thirds of the breadths of the beds in from the face of the work.

No joint to exceed three-sixteenths of an inch in thickness.

The courses to be arranged with as much uniformity as possible, and laid perfectly horizontal, the lighter courses being kept towards the top of the structure.

The vertical joints of each course not to have less than 6 inches lap over the joints of the course next below. The work to be thoroughly well grouted after every course.

Ashlar in Copings.—The coping stone will as a rule be dowelled, but the Engineer may dispense with this system in such cases as he may deem expedient.

No stones in the ashlar copings to be less than 2 feet 6 inches long, and the exposed surfaces to be dressed to a smooth face.

Ashlar Arch Stones.—Ashlar arch stones, which are in all cases to be of the entire thickness of the arch, are to be carefully and accurately wrought, giving the proper radiating, or summering joints.

The intrados to be fair broached; the beds and joints fairly wrought and left full; the last or keying course is to be very accurately fitted, and driven into its place with heavy wooden beaters.

The face stones of ashlar arches may be tooled or rock-faced, and with or without a chamfer, as may be directed.

Exact uniformity will be required in the thickness of each course of arch stones, and in the oblique arches great care is to be taken to dress the beds to the wind required by the obliquity of the arch.

Large Rough Stone Blocks.—It may be necessary to use one or more courses of rough stone blocks in the foundations of bridges; such blocks to be only quarry scabbled, and none less than 8 inches thick or less than 8 square feet in area. These blocks to be measured half as ashlar, half as rubble; they are to be laid in mortar, and great care is to be taken that they rest evenly on their beds.

Coursed Rubble Facing.—This class of work will be extensively used. In bridges up to 20 feet span no course to be less than 3 inches in thickness. When the span exceeds 20 feet the minimum thickness of a course to be 4 inches.

In structures other than bridges the minimum thickness may be 3 or 4 inches, at the discretion of the Engineer. No stone to be less than 9 inches along upon the face, or less than 8 inches on the bed.

In courses of 6 inches and upwards, no stone to have a bed less than one-third more than the thickness of the course in which it occurs.

One-fifth of the whole length of each course to be headers.

No header to be less than 2 feet long. All rubble quoins to be formed of header-stones laid alternately along each face.

The vertical joints of each course not to have less than 3 inches lap over the joints of the course next below.

The joints in all cases to be dressed as far back from the face of the work as the thickness of the course in which they occur.

The beds are to be dressed level so as to rest evenly on the mortar without any hollows or projections.

The faces of the stones to be left rough, but no part to project more than 1 inch beyond the face arrises, which are to be in all cases chipped off square.

The joints to be dressed square, true, and full, and no mortar joint to exceed half an inch in thickness; and the average of the joints to be under half an inch.

Face-work of this nature will be measured one-fifth more than the breadth of the courses, to compensate for the headers, on the same principle as is noted in the specification of ashlar.

Arrangement of Courses.—All the courses are to be kept perfectly horizontal, but uniformity in the thickness of each course throughout its entire length will not be insisted on. Every care must be taken to ensure proper skill in the arrangement of the work generally, and especially where changes in thickness of the courses occur; and where ashlar quoins or courses are used *with* the rubble, the latter must be brought up to the ashlar with a perfectly level bed.

The thicker courses are to be used in the lower portions of the work, and are also to be selected for the building of the piers and abutments or other important walls.

At every 2 feet in height it will be necessary to bring the masonry to a perfectly horizontal bed throughout the entire length of each particular wall, and to thoroughly well grout the whole.

In all stone-work the stones are to be laid on their natural beds.

In all cases where battering walls are required the beds of the stones are to be at right angles to the batter.

The face joints in all stone-work are to be raked clean and neatly pointed, and the whole work carried on and completed to the entire satisfaction of the Engineer.

Rubble Backing.—Is to be of the best materials and workmanship, built of good sound stones. No stone to be of smaller size than one quarter of a cubic foot.

The stones of the rubble backing to be carefully set and well bonded with themselves and with the face-work. The whole to be laid flush in mortar so as to leave no spaces.

The interstices between the stones to be filled in with spauls or quarry chips. The larger stones to be roughly picked when necessary, so that they may rest evenly on their beds without hollows.

The rubble backing to be brought up flush with the face-work for every

2 feet in height of the walls, and well grouted; and in no case will the building of the backing be allowed to proceed in advance of the face-work.

The joints in the back of all rubble walling to be raked and completely rough pointed.

Coursed Rubble Arching.—This work will be composed of stone similar to the headers required for coursed rubble face-work; no stone to be less in length than the thickness of the arch, or less than 1 foot in breadth.

In arches up to 20 feet span, no course to be less than 3 inches in thickness, and in arches over 20 feet span, no course to be less than 4 inches in thickness.

The arches will be built in alternate courses of headers and stretchers, or otherwise as may be from time to time directed by the Engineer.

The headers in all cases must extend right through from the intrados to the extrados of the arch unless otherwise ordered, and be not less than 12 inches wide.

The stones in the face rings must in all cases extend right through from intrados to extrados, and in bridges of 20 feet span and upwards, these face stones must be alternately not less than 15 inches, and not less than 21 inches long upon the intrados face.

The stones to be dressed and summered true and out of winding, so that no joint shall with its mortar exceed three-eighths of an inch in thickness, and the joints throughout must average less than three-eighths of an inch.

The face ring and intrados in this class of arching may be fair broached or rock-faced at the discretion of the Engineer.

All joints on the face-work and intrados to be raked and properly pointed, and the whole work made clean and neat.

Stone Pitching.—To be of the same class of stone as the rubble face-work; the face to be kept roughly dressed, and the stone to be as nearly as possible of an uniform depth. This pitching will be set on a layer of concrete or rubble, not less than 6 inches thick as described for backing, and the whole must be thoroughly well grouted.

Schedule of Prices.

The prices in the following schedule are intended to be for work finished complete in every respect as shown in the drawings, described in the specification, or ordered during the continuance of the contract. They must

therefore include all charges for superintendence, labor, materials, patterns, moulds, fittings, painting, and erecting; for temporary works and buildings; for machinery, tackle, plant, and tools of every kind, and for all lighting and watching.

The net measurement or weight of the work in place will always be taken; but no deductions will be made in masonry for grout nicks, or joggle holes, or in timber for mortices and tenons, or sinkages for fitting iron-work. No allowance will be made for scarfs.

The excavations for foundations, road or river diversions, drains and line cuttings as distinguished from side cuttings, will be measured in the cutting. All banks made from side cuttings will be measured from the sections.

The prices for the banks and cuttings must include clearing ground as specified. The ground is covered with dense jungle for about 25 miles in all; the remainder of the line is more or less open or cultivated.

WORKS.	R.	A.	P.
Earthwork, including trimming of slopes, as specified, per 1000 c. ft.,	8	4	0
Excavation of foundations in soil, clay, gravel or sand, where no pumping or baling is required, including all planks, shores, struts, and refilling, &c., per 1000 c. ft., ...	10	0	0
Excavation of foundations in soil, &c., where pumping or baling is required, per 1000 c. ft, ...	50	0	0
Excavation of foundations in soil, &c., where a timber coffer-dam or sheet piling is required, including cost of coffer-dam or piling, pumping or baling, per 1000 c. ft., ...	500	0	0
Excavation of foundations in rock where no pumping or baling is required, per 1000 c. ft., ...	100	0	0
Excavation of foundations in rock where pumping or baling is required, per 1000 c. ft., ...	150	0	0
Rock cuttings on line, per 1000 c. ft., ...	50	0	0
Gravel cuttings on line, per 1000 c. ft., ...	12	0	0
Grassing slopes of all embankments or cuttings, per 1000 s. ft., ..	1	12	0
Extra lead in forming line embankments from line cuttings when ordered, for every 300 lineal feet of average lead along the line, per 1000 c. ft., ...	4	0	0
Ballast for main line and sidings, laid and trimmed, per 1000 c. ft.,	45	0	0
Road metalling, the quantity to be measured after ramming, per 1000 c. ft., ...	60	0	0
Smooth-faced or tooled ashlar masonry not in arches, per c. ft., ..	1	12	0
Smooth-faced or tooled ashlar masonry in arching, including centering, per c. ft., ...	2	12	0
Fair-broached and rock-faced ashlar masonry not in arches, per c. ft., ...	1	8	0

WORKS.—(*Continued.*)

	R.	A.	P.
Fair-broached and rock-faced ashlar masonry in arching, including centering, per c. ft., ...	2	8	0
Coursed rubble masonry in face-work of every description except arching, per 100 c. ft., ...	50	0	0
Coursed rubble masonry in arching, including centering, per 100 c ft, ...	70	0	0
Rubble masonry in backing of walls and haunches of arching per 100 c ft., ...	26	0	0
Stone pitching as specified, per 100 c. ft., ...	46	0	0
Brickwork not in arches, per 100 c. ft, ...	42	0	0
Brickwork in arching, including centering, per 100 c. ft., ..	62	0	0
Khoa work, per 100 c. ft., ...	50	0	0
Concrete, per 100 c. ft., ...	26	0	0
Plastering, ½ inch thick or under, per 100 s. ft., ...	5	0	0
Plastering over ½ inch to 1 inch thick, per 100 s. ft., ...	8	0	0
Well-sinking, per centage on actual cost of sinking, as specified, per cent, ...	25	0	0

PERMANENT WAY.

Carriage of sleepers from jungles, and depositing them alongside of line, including loading and unloading, per 100 sleepers per mile,	5	6	0
Carriage of permanent way, &c., along the top or side of line, or on unmetalled roads, including loading and unloading, per ton per mile, ...	0	10	0
Carriage of permanent way, &c., along the Deccan or other metalled road, including loading and unloading, per ton per mile, ..	0	6	0
Maintenance of line for twelve months after opening the same, as specified, per mile, ...	1,000	0	0
Providing, fixing, working, and maintaining the Electric Telegraph, as specified, ...	1,45,000	0	0

STATIONS AND STATION BUILDINGS.

Lime whiting, in two coats, as specified, per 100 s. ft., ...	1	0	0
Glass-pannelled doors and windows, inclusive of frames, measured in the clear inside of frames, per s ft., ...	3	8	0
Timber-pannelled doors, inclusive of frames, measured in the clear inside of frames, per s. ft., ...	3	0	0
Jill-mill or venetian doors and windows, inclusive of frames, measured in the clear inside of frames, per s. ft,..	3	0	0
Timber in roofs and architraves, per c. ft., ...	4	0	0
Wrought-iron in tie-bars, straps, belts and nuts, &c., per lb., ..	0	5	0
Cast-iron in water-pipes, sockets for beams, and other miscellaneous castings, per cwt., ...	25	0	0
Wrought iron in roof or floor girders, skew backs to arched roofing, &c., per cwt., ...	25	0	0

No. LIII.

INDUS SILT EXPERIMENTS.

Description of the mode adopted in taking the Observations recorded below, to determine the Velocity of, and the amount of Solid Matter in, Water at different depths in the Indus, and in some of the Canals in Sind. By Colonel Tremenheere, R.E., *Chief Engineer in Sind.*

Plate V., Fig. 1, represents the instrument used for taking the velocities, and is a modification of Woltmann's Mill. It was fitted to a round pole, 16 feet long, and guided by a groove. An iron cross-head fixed to the top of the pole shewed the direction of the instrument, which could thus be made to correspond with that of the surface current. The correctness of the instrument had been previously ascertained by trials. The number of revolutions made by the vanes in a measured distance, when dragged through still water, at various velocities, was found in each case to correspond.

The observations on the river were taken from a boat fastened to the bank. The instrument was clamped to the pole at the required depth. As soon as the pole was in an upright position, with the cross-head in the proper direction, the trigger was pulled. The vane was usually allowed to revolve for 30 seconds, when the trigger was dropped, and the result registered by the index recorded. The observations were in every case repeated; no single observation was relied on, and whenever there was any material difference between two experiments, the observations were continued.

The observations made in Canals were taken also from a boat, either anchored in the middle, or moored to a rope stretched across between the banks. In one experiment, viz., on the Oomercus, the regulating bridge was made use of, and the observations taken in the waterway of one of the arches.

In very strong currents, such as that at A on the sketch, and at any depth below the surface, the instrument gives readings which vary considerably from one another; but this is owing to the difficulty of holding the rod in the direct line of the current, and to its vibration, but even in such cases it is not difficult to obtain reliable results. The following observations were taken at this spot:—

No of Observation.	Revolutions.	No. of Observation	Revolutions.
1	183½	5	194
2	226	6	204
3	233	7	233
4	225		

It may perhaps be taken for granted that the 2nd, 3rd, 4th, and 7th are nearly correct, and that the instrument was not held quite in the direction of the stream in the other cases. The mean of the above four gives 229 revolutions, equivalent to $9\frac{1}{2}$ feet per second, or very nearly $6\frac{1}{2}$ miles an hour.

In every case the observations for velocity were taken first, and then the samples of water were drawn from corresponding depths. The apparatus employed to effect this is shewn in Plate V., Fig. 2. The iron rod, on which the bottle could be fixed at any required height above the foot, was 14 feet in length. The valves or cocks were worked by strings fastened to the brass slide, and passed over pulleys at both ends of the rod. These valves were smaller than they ought to have been made, and did not allow the air to escape from the bottle so fast as was desirable, but this did not affect the correctness of the observations. The water so drawn was at once put into bottles arranged in order in a box made for the purpose, and the whole then carefully filtered. The filters previous to use were adjusted in the usual manner, and with the deposit were thoroughly dried on a sand bath, and weighed in opposite scales. The quantity of water was accurately measured in the usual graduated glass measures, and the specific gravities were obtained by means of the specific gravity bottle.

RECORD OF OBSERVATIONS TO ASCERTAIN THE AMOUNT OF SILT CONTAINED IN THE WATER OF THE INDUS, AND IN CANALS OF UPPER SIND, BY COLONEL TREMENHEERE, R.E., IN THE MONTHS OF JULY AND AUGUST 1864.

Date.	Site.	Gauge.	Depth of Water.	Depth from Surface.	Velocity per Second	Quantity of Water.	Deposit on Filter.	Proportion of Silt to Water.	Specific Gravity of Silt.	Remarks.
		Ft. In.	Ft. In.	Ft. In.	Feet.	lbs. oz. drs.	Grains.			
July 23,	Sukkur A,	10 11	10 0	6 10	9·5	2 2 5	62	1-244		
						1 1 1½	36	1-208		
						0 14 0	26	1-235		
						4 1 6½	124	1-232 = ·00431		
July 25,	" C,	11 4	8 6	6 10	3·5	2 0 0	50	1-280		
						1 13 0	51	1-248		
						1 15 0	47	1-288		
						5 12 0	148	1-272 = ·00368		
July 27,	" B,	11 8½	8 9	3 9	4·58	2 4 2	72	1-220		
						2 2 6	75	1-202		
						1 13 4	63	1-204		
						6 4 4	210	1-209 = ·00478		
July 28,	" B,	11 11	9 2	6 2	4·2	2 2 3¾	64	1-235		
						1 12 1½	51	1-241		
						2 3 3	85	1-182		
						1 12 2	70	1-176		
						7 14 2¼	270	1-204 = ·00490		
July 29,	" D,	11 11	12 0	10 0	3·1	1 14 0	57	1-230		

						1 9 6	73	1-154		
						2 4 0	70	1-225		
						2 4 4	78	1-204		
						8 0 2	278	1-202 = ·00495	2 317	
Aug. 1,	Sukkur D,	12 2	8 6	6 6	2·6	2 3 3	62	1-249		
				4 6	3·2	2 3 3	59	1-262		
				2 6	4 0	2 2 6⅓	47	1-317		
				1 0	4 2	2 3 3	50	1-390		
						8 12 1⅓	218	1-281 = ·00356		
Aug. 3,	„ B,	12 3½	9 6	7 6	3 8	2 3 0	62	1-247		
				5 6	4·1	2 0 0	65	1-205		
				3 6	4·6	1 12 3	49	1-253		
				1 6	3·5	1 8 0	39	1-269		
				0 6	3 9					
						7 7 3	215	1-242 = ·00413		
Aug. 9,	„ C,	13 0	8 6	6 6	3 6	1 13 2¾	47	1-272		
				4 6	4·1	2 0 5	50	1-288		
				2 6	5·2	1 4 4½	26	1-346		
				0 6	5·4	2 1 0	48	1-300		
						7 3 4¼	171	1-295 = 00339	2 464	
		Total, ..	....	... .	....	55 7 7⅓	1634	1-237 = 00422		Mean result of all observations at Sukkur.
Aug. 3,	„ B,	12 3½	11 0	8 6	About 4 feet,	13 3 0	449	1-205		Total weight of deposit, 904 grains.
						Sand,	228	1-405		Sand 228 Mud 221.
						Clay,	221	1-418		„ 224 „ 231.
Aug. 9,	„ B,	13 0	11 0	10 0		13 12 4½	455	1-212		452 452, or exactly half.
						Clay,	221	1-417		
						Sand,	224	1-430	2·688	Sand only.

Date.	Site.	Gauge.	Depth of Water.	Depth from Surface.	Velocity per Second.	Quantity of Water.	Deposit on Filter	Proportion of Silt to Water.	Specific Gravity of Silt	Remarks.
		Ft. In.	Ft. In.	Ft. In.	Feet.	lbs. oz. drs.	Grains.			
July 28,	Floating down Pass between Sukkur and Bukkur,	11 11	80 to 90 feet.	11 9	Not observed.	2 4 0	75	1-210		
Aug. 13,	Floating down near Seeta in centre of current,	13 3	Unknown.		Do.	1 12 0	57	1-215		
						4 0 0	132	1-212 = ·00472		
July 30,	Mouth of Nara Supply channel below the Arore,	12 0	12 0	10 0	3 6	2 4 5	67	1-239		
						2 5 2½	97	1-166		
						2 1 3	32	1-456		
						2 4 7¼	60	1-269		
						1 2 3	27	1-297		
						10 2 4¾	283	1-251 = ·00398		
Aug. 2,	Supply channel half way to Regulator in centre of channel,	12 3	8 2*	6 2	2 9	1 10 3	40	1-288		* Shews a deposit of at least 6 feet in depth in the bed.
				4 2	2 8	2 5 0	61	1-265		
				2 2	4 2	2 5 6	46	1-359		
				0 8	4 9	2 5 2	38	1-428		
						8 10 3	185	1-327 = 00306		
July 26,	Oomercus Canal Bridge,	11 6½	6 10	2 10	2 08	1 14 7½	53	1-255		
						1 11 2½	42	1-284		
						1 9 6	40	1-281		
						5 4 0	135	1-270 = ·00370		

Aug. 12,	Mouth of Ghar,	13 1½	11 8	9 8	2 9	1 13 2	42	1-304
				7 8	2·7	2 2 6	54	1-281
				5 8	3 1	1 9 2¾	36	1-308
				3 8	3·1	2 4 5¾	51	1-315
				0 8	3·2			
		Bukkur Gauge.				7 14 0½	183	1-301 = 00332
Aug. 5,	Ghar at Larkhana,	12 7 15 11 on lower side of bridge	12 0	10 0	2 1	2 5 3½	36	1-455
				8 0	2 2	2 3 0	37	1-414
				6 0	2 8	2 4 4	39	1-409
				4 0	3·0	2 5 4	34	1-482
						9 2 3½	146	1-438 = ·00228
Aug. 6,	Humeer Canal,	Bukkur, 12 8	8 0	6 0	2 0	2 5 0	44	1-368
				4 0	2 4	2 5 4⅓	43	1-382
				2 0	2 5	1 15 0	30	1-449
				0 8	2 5	2 2 6	32	1-475
						8 12 2⅓	149	1-412 = 00243
Aug. 7,	Gharree Sind Gaheeja,	12 8	11 6	9 6	3 0	2 2 2	9	1-1665
				7 6	3 5	2 3 2	8	1-1927
				5 6	3 7	1 12 1½	10	1-1233
				3 6	3 5	2 4 4¾	6	1-2668
				0 6	3 5			
						8 6 2¼	33	1-1780 = ·00056
Aug. 8,	Sind Shikarpore,	12 9	8 0	6 0	2 3	2 5 0	37	1-437
				4 0	2 6		Filter broken.	
				2 0	3 0	1 15 1⅓	25	1-545
				0 6	3·1	2 5 2½	26	1-628
						6 9 3⅚	88	1-524 = 00191
	Kotree [bank, River				2 4	8 10 2	192·5	1-314 = ·00318

Observations on the above.

The mean result of 29 observations taken at Sukkur is that the silt amounts to the 1-237th (·00422) part of the water by weight; but, adding the two observations taken on August 3rd and 9th, it amounts to the 1-227th (·00441.) The addition of that taken on July 28th leaves the last fraction unaltered. The experiments at B on the 3rd and 9th August are remarkable for agreeing so closely with each other; the proportion of sand and clay in the two combined being exactly one-half of the deposit. In these cases the sand was easily separated from the clay; as the sand settled at the bottom of the vessel the water containing the clay in suspension was thrown on the filters; the residue was then washed with portions of the clear water, which was then again passed through a filter, the same course being repeated until the water after agitation appeared to be quite free from discoloration. The result is, that the River water contains about 1-210th (·00476) part of its weight of matter in suspension. One-half, or 1-420th (·00328) part consists of clay, and the other half of sand of specific gravity varying between 2·430 and 2·688, or from 150 to 168 lbs. per cubic foot. The observations in the Eastern Narra supply Channel give exceptional results. The regulator being to a great extent closed, the top water was comparatively clear, though running at a high velocity.

The observations at the Oomercus and the mouth of the Ghar shew perhaps the ordinary proportion of silt in Canals led direct from the River, at a short distance from their mouths, which may be stated at 1-300th (·00333). The two following observations of the Ghar at Larkhana, and the Hummer, a branch of the Ghar, indicate that about one-third of the heavy material carried into the Canal, or 1-900th of the whole had been deposited before those points had been reached, leaving about 1-450th still in suspension. The Sind at Shikarpoor, a Canal which does not derive its water directly from the River, was found to contain only 1-524th (·00191). The most remarkable case is that of the Gharree Sind, in which an unusually small amount of silt was found. This is a case in which the Canal is supplied during the height of the inundation from water which is naturally filtered by passing across an island covered with low jungle and high grass.

It must be admitted that a more extensive series of observations is

desirable, but the table given above appears to point to the following conclusions, which may perhaps for the present be accepted:—

1st. That the water in Canals which derive their supply from branches separated from the main River by islands covered with brushwood and long grass, contains a comparatively small amount of material in suspension.

2nd. That the water in Canals whose head is on the main stream, where the velocity of the current is not exceptional, may be expected to contain an amount of sand and silt equal in weight to about 1-300th of the weight of the water, and that one-third of this, or 1-900th, will be deposited in the bed of the Canal within a distance of its mouth which will vary with the velocity maintained in the Canal.

3rd. That Canals constructed so as to derive their supply from a part of the River where the section is contracted, and the velocity is much augmented and exceptional, will probably contain sand and silt varying from 1-200th to 1-250th, the half of which, or 1-400th to 1-500th, will be heavy sand, which will be deposited in any Canal in which the velocity is so low as $1\frac{1}{2}$ or 2 feet per second.

The former rulers of Sind appear to have well understood the peculiarities of the River, upon which the prosperity of their country so entirely depended, and to have studiously selected spots for the Canal heads which are screened from the full force of the current during the inundation. The point which particularly strikes an Engineer, or even a non-professional man in travelling up the River during the inundation, is the absence of almost all signs of Canal irrigation on the banks. He has been told, or he is aware, that nearly the whole Revenue of the Province is dependent upon Canals which are led off from the River, and whose branches cover the whole country with a perfect network of water channels, but he looks almost in vain for any signs upon the River banks of such a system being in operation. From Kotree the whole way to Sukkur he passes the mouths of only two Canals* of any size on the left bank which are taken directly from the main stream, and both these he finds on enquiry have been dug by the British Government. It is the same on the right bank: omitting the natural channels of the Arul and Narra, the Ghar is the only Canal upon the River bank, and its present mouth is also the work of our own Government.

* The New Foolailee and the Nusseer.

It may be useful to add a calculation of the amount of sand which would be deposited on the first few miles of a Canal with a bottom width of 30 feet, side slopes of $1\frac{1}{2}$ to 1, bed slope 4 inches per mile, and a depth of 10 feet, giving a discharge of 750 cubic feet per second, the amount of solid matter in the water being 1-250th, the half of which is sand.

$$750 \times 60 \times 60 \times 24 = \text{cubic feet per diem} = 64{,}800{,}000.$$

$$\frac{64{,}800{,}000 \times 62\frac{1}{2}}{500} = \text{weight of deposit per diem} = 8{,}100{,}000 \text{ lbs.}$$

$$\frac{8{,}100{,}000}{168} = 48{,}214 \text{ cubic feet, or } 4{,}821{,}400 \text{ cubic feet in 100 days.}$$

As such a Canal should be kept open for at least 300 days in each year, some allowance should be made for the deposit, which, supposing the mouth not to be closed by the above quantity of sand, would take place in the additional period of 200 days; but as the River would not be in flood for the larger portion of this period, the proportion of silt carried by the water would decrease. The Canal also could not be maintained at so high a level for so long a period.* It is impossible under these fluctuating circumstances to make any calculation of the additional amount of deposit during the above time; it may suffice to make the supposition that the accumulation during these 200 days may be one-half the quantity deduced above for 100 days, which will give a total of 7,232,100 cubic feet. The smaller of the above quantities, viz., 4,821,400 cubic feet, if spread in an even slope over a length of 7 miles of the Canal, would give a depth of 7 feet of deposit at the head. This, as it would leave less than 3 feet as the maximum depth of water available between the 15th of October and the 5th April, would render the Canal useless for the purpose for which it was proposed, viz., to afford a perennial supply, and to irrigate the Rubbee crops.

Another case may be stated,—that of a Canal taken from the same point, with a bottom width of 35 feet, side slopes, of $1\frac{1}{2}$ to 1, bed slope 4 inches per mile, a depth of 6 feet, and discharge 400 feet per second. The proportion of solid matter being the same as in the former case, we have:—

$$400 \times 60 \times 60 \times 24 = \text{cubic feet per diem} = 34{,}560{,}000.$$

$$\frac{34{,}560{,}000 \times 62\frac{1}{2}}{500} = \text{weight of deposit per diem} = 4{,}320{,}000 \text{ lbs.}$$

* From observations made, extending over 15 years, a Canal with its bed 6 65 feet below zero on the Bukkur Gauge would carry a depth of 10 feet for 230 days.

$$\frac{4,320,000}{168} = 25,714 \text{ cubic feet, or } 2,571,400 \text{ cubic feet in } 100 \text{ days.}$$

As the velocity in this case would be only 17 inches per second, as compared with 20 inches in the previous example, the limit which the sand would reach may be stated at 6 instead of 7 miles, and the depth of the deposit at the head of the Canal at $4\frac{1}{8}$ feet. The bed in this case may be taken at 5 feet below zero on the Gauge. With 4 feet deposit, the depth of water in the Canal, as ascertained by the Gauge Returns, between the 15th October and the 15th March, would vary from $4\frac{1}{2}$ feet to 1 foot 7 inches. The discharge at these depths would be quite inadequate to water the extent of country for which the Canal would be required.

The circumstance that the deposit will not assume an even surface extending over a distance of 7 miles has not been overlooked: were it to do so, the bed slope would be increased to 1 foot 4 inches a mile, and the velocity would be greatly augmented, and the sand carried forward. The actual form it will assume cannot be determined, although with a fixed discharge the quantity of sand deposited, as far as these experiments are reliable, may be stated with an approach to accuracy. The sand will probably form ridges, which near the head of the Canal may very possibly exceed the height deduced in the calculations, in which case the effective discharge would be reduced still earlier in the season.*

The results to which the consideration of these experiments appear to point are—

1st. That Sukkur is not a suitable spot for the head of a Canal.

2nd. That if a Canal be opened at that place, the deposit of sand, near its head will be so great during the inundation that it will not be effective for Rubbee cultivation.

Postscript.—It may be interesting to consider the amount of solid matter which must be carried down by the Indus. The discharge of the River at Sukkur during the inundation, with a depth of 13 feet on the Gauge, amounts to 3,80,000 cubic feet per second. On the supposition

* On the supposition that the Gates proposed by Lieut.-Colonel Fife, in No. III., Vol I., of Professional Papers on Indian Engineering, were applied at the regulator of such a Canal, and the level of the floor 6·65 feet below zero on the Gauge, the depth of water on the outer side in the height of the inundation would be 20 feet. The top of the middle piece being 5 feet 11 inches above the floor of the regulator, the depth over it would be 14 feet 1 inch, and seven openings 10 feet by 6 inches, would maintain a depth of 10 feet in the Canal, the water to supply which would be drawn from a mean depth of 13 feet 10 inches from the surface, the Canal supply would consequently not be obtained from the top water. The above depth considerably exceeds that at which any of the experiments given in the table were made, and it is reasonable to conclude that the proportion of sand would rather exceed than fall short of that made use of in the above calculations.

that only 2,50,000 cubic feet are discharged into the sea for 100 days, and that the water so discharged contains the same proportion of silt as it has been ascertained to hold at Sukkur, viz., 1-250th part, the total quantity will be found to exceed 119 millions of cubic yards, or sufficient to cover a surface of $38\frac{4}{10}$ths square miles, with a deposit 1 yard in thickness.

It may be observed that the actual quantity of sand and silt moving forward with the current must be the same in each section of the River. The rule which is applicable to the uniform discharge of water in different river sections must apply equally to the solid material held in suspension. Where the velocity is exceptional, as in the narrow pass at Sukkur, the water and sand are more intimately mixed, and the surface water will contain a larger proportion of sedimentary matter than elsewhere, but the total quantity of solid matter is no more affected by the additional velocity than is the volume of water discharged by the River.

C. W. Tremenheere, Colonel, R.E.

Note by Editor.

Exact details of the whole process of filtering above described would be very useful.

It is to be regretted that these very valuable observations were not taken in every month of the year; observations made in July and August alone must give an exaggerated idea of the quantity of silt contained in the river.

In the case of the Indus Innundation Canals of the Lower Derajat, most of them have their mouths on the main stream of the river, though it is quite possible they may have been cut from a branch in the first instance, and the set of the water down the Canals may have had some influence in converting the branch into the main stream. No doubt the beds of such Canals as a rule silt up very much, but the chief cause of that I have always attributed; 1st, To the want of any outlet at the tail, owing to which the silt is carried forward, heaped up, and has no escape; and 2ndly, To the great sinuosity of their channels. Were these channels straightened so as to increase the available slope of their bed and a scour maintained by tailing them (where possible) into a nullah or back into the river, the deposit of silt would be very greatly diminished.

The following Silt Estimates were made by H. B. Medlicott, Esquire, (of the Geological Survey) on the water of the Ganges River and Canal, and were published in the Asiatic Society's Journal, Vol. XX., Parts 3 and 4.

SILT ESTIMATES, PARTS IN 10,000.

No.	Date.	Hurdwar.	Asufgurh.	Roorkee.	
1	4 May, 1856 ..	2 03	·33	3·37	
2	1 May, 1857 ..	·09	..	1·28	
3	1 May, 1858 ..	..	..	..	
4	22 May, 1861 .	..	..	3·82	
5	5 June, 1856 ..	6 05	7·34	5 19	4 feet of water at Roorkee
6	10 June, 1857 ..	6·88	..	2·75	4 feet of water at Roorkee
7	1 June, 1858 ..	3·41	..	3·85	
8	13 June, 1861 ..	13·65	..	..	
9	4 July, 1856 ..	14·50	8 00	11 79	
10	4 July, 1857 ..	10·45	..	5·17	
11	2 August, 1856	23·10	13·30	26 10	
12	2 August, 1857	17·93	..	5·83	
13	2 Sept., 1856 ..	6·89	81·00	7·66	
14	1 Sept., 1857 ..	5·39	..	..	
15	4 Oct., 1856 ..	clear	..	·85	
16	1 Oct., 1857 ..	1·98	..	1·00	
17	5 Nov., 1857 ..	·61	3·30	2·20	6·5 feet of water at Roorkee
18	1 Nov., 1857 ..	·44	..	..	
19	1 Dec., 1856 ..	·20	1·43	·55	
20	1 Dec., 1857 ..	clear	..	1·32	
21	1 Jan., 1857 ..	..	·45	1·67	
22	1 Jan., 1858 ..	clear	..	1·32	
23	1 Feb., 1857 ..	1·02	·12	1·26	
24	1 Feb., 1858 ..	..	..	..	
25	1 March, 1857	..	1·27	·99	
26	1 March, 1858	..	..	..	
27	1 April, 1857 ..	·37	·45	·82	
28	1 April, 1858 ..	..	..	..	

Hurdwar is where the Ganges leaves the Siwalik hills to enter upon the plains; the stream is much more rapid there than lower down. Asufgurh is on the Ganges, about eighteen miles below Hurdwar. Roorkee is eighteen miles below Hurdwar, on the Ganges Canal. These estimates are of course exclusive of the soluble ingredients. If the single series of estimates from Asufgurh for 1856-1857 can be trusted, they seem to indicate approximate equality with Hurdwar during the period of low water; a very decided diminution during the period of greatest flood, involving a very considerable deposition along the bed and low branches of the river below Hurdwar, and a marked increase about the rise (from snow-water) and fall, before and after the rains in the mountains have charged the river with sediment, the lower reach of the river thus preying on its muddy banks. No. 13, from Asufgurh, may be questionable; for all the samples from there I had to depend upon a native messenger.

The proportion of silt in the canal water at Roorkee, as compared with the head, seems to depend upon the depth of water, producing either silting-up or erosion.

Some cases, show how very indefinite such silt estimates must sometimes be ; samples collected by myself at the same time, in the same way, and with equal care, showing a difference of a third—See 6 and 7.

OCCASIONAL SILT ESTIMATES, PARTS IN 10,000.

No.	Date.		
1	4 July, 1856 ..	Solani at Roorkee, a 3 feet flood	47·30
2	16 July, 1856 ..	„ „ 3·5 feet flood	93·90
3	19 July, 1856 ..	„ „ 6 feet flood	80 00
4	19 July, 1856 ..	„ „ same time as No. 3 ..	87·10
5	22 Sept., 1856 ..	„ „ 5·5 feet flood	68·50
6	31 July, 1857 ..	„ „ 9 feet flood	228·80
7	31 July, 1857 ..	„ „ same time as No. 6 ..	148·50
8	1 June, 1861 ..	Jumna, at Canal head	1·04
9	10 June, 1861 ..	„ „	3·05
10	1 June, 1861 ..	E. Jumna Canal, 96th mile	10·50

No. LIV.

OIL-MILLS FOR THE EAST INDIAN RAILWAY.

From the Agent East Indian Railway, to the Consulting Engineer to Government of Bengal, Railway Department.

Calcutta, April 13th, 1864.

SIR,—I have the honor to forward an indent with design and estimate for a pucka shed for four Oil-mills, to be erected on the Railway Company's ground at Mokameh. The Chief Engineer states that, the stations of Barh and Mokameh would both be well situated for the erection of Oil-mills, as there is a large quantity of castor oil grown in the neighbourhood; but, of the two, Mokameh would be the best adapted for the purpose.

Mr. Campbell has submitted a tracing of Messrs Shanks and Carrick's Oil Press, which I forward herewith, together with a memo. by Mr. Carrick. Mr. Campbell states that, from his own knowledge of this press, he can recommend it as being the best and most economical of any in use in this country.

The cost of each Oil Press complete and ready for fixing is Rs. 650 each; five of them will produce 9,000 gallons of oil per month. The amount of the indent is Rs. 8,176, which includes cost of shed, construction of oil presses and fixing of the same.

The Company is the largest consumer of oil in India, and oil it must have at any price and whatever the quality, unless it can be placed beyond the power of the manufacturers.

This was so fully exemplified in the N. W. Provinces, that I obtained

in 1862, the sanction of that Government to manufacture oil, the cost of which had run up solely owing to the requirements of the Company, to 12 rupees per maund. The average cost at which it was produced from the commencement up to April last, was about Rs. 7-5-2 per maund, and the saving effected upwards of Rs. 12,000. This, however, by no means represents what the saving would have been if the single oil-mill erected at first could have turned out the whole quantity required by the Company, although it had the effect of bringing the bazar price down 25 per cent. for the balance.

The out-turn has been fairly debited with its legitimate charges, and as soon as the concern was in proper working order, with an additional charge of 12 per cent. per annum on the value of the block. Rent was not charged, only because the manufacture had been carried on in an abandoned temporary workshop at Allahabad, pending construction of a building at Etawah in the centre of the seed districts, the rent for which would be met by a reduction in the freight of seed.

The price in Calcutta, and up the line in the Bengal Division, is from Rs. 12-4-0 to 13 per maund of oil; and I have been forced on more than one occasion to accept inferior oil, at the last moment or go without, either of which contingencies is a serious matter on a Railway, where safety depends upon clearly burning lights.

The consumption for this purpose on the Bengal Division amounts to about 1,000 maunds per month, and according to the supplies the ordinary trade profit of 30 per cent., the saving to be effected will scarcely be less than Rs. 4,000 a month, and while manufacture itself is so simple that it does not require any unusual qualifications to carry it on.

I have, &c.,

CECIL STEPHENSON.

Estimated cost of erecting shed at Mokameh Station, to contain four Oil Screws with Boilers and Crushing Rollers, with godown attached: length of building 100 × 30 feet.

c. ft.		RS.
13,000	Brick-work, at Rs. 15 per 100, - - - - -	1,950
s. ft.		
3,000	Floor paving, at Rs. 12 per 100, - - - - -	360
4,000	Roofing, at Rs. 22 per 100, - - - - - -	880

No. LV.

THE INDUS TUNNEL.

Abridged from a Report upon the Indus Passage at Attock, on the line of the Trunk Road, and on the means of providing for it in the best and most economical manner, prepared agreeably to the Orders of the Government of India. BY LIEUT.-COL. ALARIC ROBERTSON, *Superintending Engineer.*

THE Fort of Attock is situated just below the junction of the Cabul river with the Indus, and at the gorge where the united rivers enter the hills, which extend from Attock to Kalabagh. The river gradually contracts in breadth as it approaches the fort, forming a sort of funnel mouth, the fort being situated at the neck; and at this point, the ferry, on the Trunk Road from Lahore to Peshawur, is worked. The bridge-of-boats is generally established just above the fort, and sometimes at the end of the season removed to a site some short distance below it; Attock is situated on the east or left bank, and on a spur of the hills which here run down to the river.

On the right bank opposite the fort, and extending up to the Cabul river and its junction with the Indus, the ground is comparatively flat, but the hills bound this small plain on the west and south, and run down to the river only a very short distance below the fort, and within rifle range of it. The old fort of Khariabad is on the south-east corner of this plain and nearly opposite that of Attock. These hills, of slate and limestone, are wild, broken, and rugged.

For many miles above Attock, the Indus flows in a wide divided stream (at no very high velocity,) through the plains of Chuch, but as

it approaches Attock, the stream becomes contracted and united; the velocity increases, and it flows past the fort, in the hot season, with a velocity of about 13 miles an hour. Colonel Crommelin,* gives the velocity above the fort, at the site of the tunnel (his Bridge, No. 1) at 5 to 7 miles an hour in the cold, and 13 to 14 in the hot season, and surmises that it is higher at the fort, but was unable to measure it in the floods. I measured the velocity of the river and calculated the discharge in December 1860. The surface velocity of the river, given as 9 miles an hour at the centre, was the mean of several observations

The contraction of the bed causes the river to rise to a great height, amounting to about 50 feet above the cold weather level of the stream in high floods of ordinary season; and a variation of level in the river, of from 5 to 7 feet in the course of the 24 hours, is not unusual.

In addition to the great height of the ordinary rise of the Indus, this river is subject to extraordinary floods, occurring at uncertain intervals, and caused by the damming up of branches of the river in the mountain valleys,† and the sudden yielding of the dam by topping or bursting. The only record we possess of these floods extends back but to 1841; from the most careful enquiries, the flood of that year appears to have risen 92 feet above the usual cold weather level of the river. The next flood occurred in 1858, and this from careful levels I found to be 80 feet above the cold weather level. There is nothing in the formation of the country, (*i. e.*, no other line of escape for the water,) to prevent a much more serious rise than either of these floods; and from the nature of their origin, there seems no reason why a much higher one should not occur at any time.

From the various causes above stated, the Indus passage at Attock is one of much difficulty and danger, and its improvement has occupied the attention of Government from the time of annexation, but up to the present, nothing has been effected beyond an improved boat-bridge in the cold weather, more efficient ferry boats for the hot season, and the addition of light row boats for the dâks, travellers, &c. I may here note, that the present ferry boats cross the stream by the aid of oars or sweeps, and are carried down a considerable distance by the strength of the current. The object aimed at, is to enter a back water which flows up river in certain

* In his Report of 1853, forwarding a design for a Suspension Bridge for two alternative sites.—[Ed.]

† By Land or Ice slips.—[Ed.]

places on each side. If this is attained, the boat is carried up by the stream, or towed in slack water, to nearly opposite the starting point and with no great delay; but if the point is missed, the boat is either dashed against the rocks and sunk, or carried down river. The ferry boats are necessarily of moderate size, and in addition to the difficulties of access to the ferry (which might be improved), there is great delay in unloading and putting carts, cattle, &c., into the boats, and in again landing them. From the difficulties of the river, more commodious platform boats on which carts, &c., could be run, cannot be introduced.

The schemes submitted for the passage of this river have been numerous, but the only one really tried, was that by Colonel Taylor, of maintaining a bridge-of-boats during the hot weather. The experiment failed, and though no doubt the difficulties might have been overcome, had Colonel Taylor been permitted to persevere, yet success could only have been looked upon as a temporary expedient, liable to too many casualties to admit of its being depended on for so important a passage as the Indus at Attock.

At the present point, it may be advisable to enter somewhat into the detail of the importance of the passage, in a military and commercial point of view.

The force in the Peshawur valley, consists of from 7,000 to 8,000 men; all the reliefs, stores and supplies have to cross the Indus at Attock; Kohat and Bunnoo are also on ordinary occasions supplied by this route, but another route by Kooshealghur is open to them.

In ordinary circumstances, all reliefs are effected, and stores sent up during the cold season when the boat-bridge is up; and it is only invalids for Murree, &c., that suffer the inconveniences of the ferry; but in times of difficulty and danger the case is altered. During 1857, batteries of Artillery, troops of all descriptions, stores, &c, had to be passed, and the delay and exposure of the men in the height of the hot season was most serious; and though we may hope to be spared another mutiny, we must always look for emergencies on the frontier, to necessitate the movement of troops at all seasons. Any disturbance with the Kuttuck tribe, who claim the hills on the west bank of the river, might close the passage unless the occupation of these hills by our troops secured it for us.

The possibility of our position at Attock being turned by any of the lower passes, and our having to fall back for a time, will be referred to when considering the different means of crossing the river.

In a commercial point of view, the trade is not very large, but still of such considerable amount as to call for some facilities being given, and to justify a moderate expenditure for that object alone. From the best information I have been able to obtain, the value of the trade crossing the Indus at Attock, amounted in 1855 to Rs. 14,87,786, and without doubt the trade has very much increased since then; the rent of the ferry at Attock in 1855 was Rs. 15,000; it is now Rs. 17,000. That the trade by this route can be much increased, I do not think probable, though every facility added to the route must have some effect, but the Afghan valleys are, I believe, cultivated almost to their utmost extent, and for the country beyond, the water carriage and shorter land route through the Persian Gulf for our own trade, and the Russian line by the Caspian sea, must limit our extension of trade through the Khybur.

I will now refer to the various projects brought forward with regard to this passage. We may divide them into—I. Those for passing the river itself. II. Those for passing *over* it. III. Those for passing *under* it. Under the first head we may class—1st, a Permanent Boat-bridge; 2nd, Flying bridges of various denominations; 3rd, a Steam Ferry.

I. Of the 1st, viz., a Permanent boat bridge—I have already I think said all that need be said on the subject; it is a temporary expedient, of too uncertain a nature, and too liable to accidents or wilful injury, to allow of its being considered as a permanent provision for the passage; though by the use of closed iron pontoons, and other precautionary expedients it might be maintained in ordinary circumstances.

Of the 2nd means, by Flying bridges—1st, by a barge anchored to a mooring in the centre of the stream, the cable supported on pontoons, and the barge crossing by the action of the current. The great variations in the level of the river would be troublesome, but the serious objection is the moving of masses of sand and shingle by the current, which would bury and run up the cable, and render it inefficient, while even if these difficulties were overcome, it would be but a temporary expedient liable to all the objections of a permanent boat bridge.

A flying bridge by a barge working on a cable stretched across the river, would also come under the head of a temporary expedient.* The varying level of the river would necessitate the lengthening and short-

* This I believe is about to be tried this season by Colonel Taylor.

ening of the attaching cable, and consequent alteration of landing places; floating landing stages would be required on the edge of the back water, or up current, which exists at the sides, and into which of course the flying bridge could not be brought, and the landing stages must be connected with the shore (these objections also apply to the other description of flying bridge.) The dangers and difficulties of working such a bridge in a current of 13 miles an hour, especially when the river is falling and runs in high waves, would be great; and it is doubtful even if the barge was not swamped in such circumstances, whether with such pressure as there would be on the block, it would travel up the curve of the cable, after it has passed the centre of the stream. Lastly, what would be the fate of the barge in case of the breaking either of the carrying or attaching cable? If the former gave way the bridge would be stopped for the season, as the cable could not be replaced until the cold weather, as boats could not be anchored out for this purpose in the floods.

All the above expedients I think may be classed as of too temporary and uncertain a nature, and too liable to accidents, to meet the requirements of the Indus passage, though I enumerate them, as I wish to make the subject as full as possible.

The last of the schemes for passing *on* the river itself is by a Steam Ferry; this was fully discussed in 1858, and all the papers on the subject published in Vol. IV., No. 3, of the Punjab Selections, so I will only say that I can add nothing to what I then stated, but that late experience at home confirms my views that boats of sufficient speed could be easily obtained. The cost of such an arrangement is however I think a sufficient bar to its adoption. The tear and wear of boats of such high speed is enormous. It has been objected to a steam ferry, that no boat, however great the power, would be manageable in such broken water, at such a high velocity; I do not think that any difficulty would be found with a short handy boat, with plenty of power; though of course a very long boat would be open to these objections.

II. The next point I purpose to consider is the means of passing *over* the river. The first difficulty that presents itself is, with our records only extending back 20 years, and with a flood within that period which rose 92 feet, and a formation of country admitting of a rise very greatly in excess of this, even 150 feet, and the course such as would appear to have no fixed limit, where are we to place a bridge?

Colonel Crommelin* in preparing his designs placed his bridge 96 feet over the low water level; this only gives 4 feet clear of a known flood, only 20 years back, while the land arches in his approaches would all be closed, even with a flood such as that of 1841; the next flood may be 120 feet, and what becomes of the bridge? These floods bring down trees, stacks of corn and fodder, huts, cattle, &c., so that even a clear space of 10 feet between the river level and the lowest point of the trussed railing or crown of arches, would not save the bridge from being carried away. But let us assume that some fixed height, 110 or 120 feet, is to be risked, what is to be the nature of the bridge? The spans should be large, for not only will the foundations be expensive, but every pier put into the river contracts the waterway, and will increase the height of the next flood, if the bridge is at the narrowest point; or contracts the water vent beyond that of the narrowest point in the immediate neighbourhood.

Colonel Crommelin gives the span of the flood of 1841 at the lower site as 1,400, and at the upper as 2,280; at the lower site, the flood extended much beyond this, but the water was shallow and probably of no high velocity; this may be said also of the upper site.

These spans are the least, I think, which would suffice for the length of the bridge. Colonel Crommelin fixes 1,125 and 1,890 feet, and proposes to provide for the great floods by the land arches in the approaches; the ordinary flood spans are given as 1,280 feet, and 1,880 feet; the width of roadway proposed, is 24 feet.

Colonel Crommelin admitting the necessity of large spans, selected the suspension principle as the cheapest means for this purpose, his estimate for the lower bridge was Rs. 9,68,635.

Suspension bridge,..	8,42,651
Approaches, ...	1,25,984

or about £3-12 per square foot of roadway for suspension bridge, not including the approaches.

The upper bridge he did not estimate. In this estimate the iron work is put down at £10 a ton, and the carriage from Kurrachee at Rs. 25. First quality bar-iron in England would cost from £16 to £18 a ton, and the chains for a suspension bridge with bolts, &c., would not I think be under £25 to £30 a ton; the Tehseeldar, at Attock, gave me the cost of freight from Kurrachee to Attock at Rs. 58 a ton.

* In his Report of 1853.

Now let us compare this estimate with the cost of suspension bridges in Europe, and let us remember that the bridge for the Indus must be made at home; and to the cost of a home-made bridge, must be added the cost of bringing it out to Kurrachee, and up the Indus to Attock, and also the difference of cost between masonry in the Indus, 110 or 120 feet high, and that of bridges at home.

The difficulties of foundations in the Indus have yet to be tried, but without doubt they will be very great; steam power alone, and that of great extent, will keep down the water, and the quality of masonry must be very fine, and the mass great, to stand against a flood of 92 feet depth running against the piers with a velocity of probably 20 miles an hour, and carrying with it timber, stacks of corn, &c., &c.

I obtain the following from the "Engineer and Contractor's Pocket Book" for 1855. Hungerford bridge, consisting of one main and two half spans; between abutments, 1,352 feet; width of roadway, 14 feet; cost, £80,000, or £4·226 per square foot of roadway. Fribourg Suspension Bridge, (lower,) span, 870; width, 28 feet; cost, £107,000, or £4·4 per square foot. Menai Suspension Bridge, span, 580; width, 28 feet; cost, £120,000, or £7·388 per square foot; but this includes the cost of seven land arches of 52·6 span. If we deduct for this, however, £10,000, which is a full rate, it still leaves per foot, £6·77. This bridge is the only one to compare with the Indus in height, &c. The Hungerford Bridge is only 31 feet above high water; the Fribourg, though high over the valley, has its piers on the bank, little below the level of the roadway.

I regret I can find no more examples, but to apply those above given, and taking a low rate, say £5 per square foot, as the cost of a bridge in England, such as is required for the Indus; to this has to be added the cost of transport of the iron-work to Attock, with the machinery to put it up; but I will not attempt to estimate this, but take simply the English cost. We have Colonel Crommelin's lower site, 1,400 feet, and upper as 2,280, these are the spans of the flood of 1841, as far as the main stream is concerned, and take Colonel Crommelin's width of road, 24 feet.

$$1{,}400 \times 24 = 33{,}600$$
$$2{,}280 \times 24 = 54{,}720$$

which at £5 per square foot, gives Rs. 16,80,000 and Rs. 27,36,000, respectively, and taking Colonel Crommelin's spans,

$$1{,}125 \times 24 = 27{,}000$$
$$1{,}890 \times 24 = 45{,}360$$

we get Rs. 13,50,000 and Rs. 22,68,000.

It is true that the span of the suspension bridge at the upper site might be reduced, and the floods attempted to be provided for by land arches in the approaches, but this would of course much contract the waterway, and I think, endanger the whole structure. This is as far as first expenditure, the cheapest bridge that could be made.

Now let us see the cost of a more permanent bridge, such as the Britannia Tube. This cost £14 22 per square foot; and as the difficulties of foundations and height may be considered similar, for the lower site, the cost without approaches, would be Rs. 47,77,920, and for the upper, Rs. 77,81,184, and what is to be added for bringing the material, machinery, &c., from Europe, and for approaches?

I do not enter upon the subject of Wooden Bridges, for I do not think in the situation, any one would advocate the use of such a material.

It now becomes necessary to consider the value of a bridge in all its bearings—1st, Military; 2nd, Permanence and current cost. It may be sufficient to look at the suspension bridge.

1st. A Bridge at the lower site is completely under rifle range from the hills, and the upper is still within long range. This of course could be guarded against by a sand bag parapet, or other precaution, but every movement could be watched; and a single gun in a short time would entirely destroy the bridge, by battering down one of the supporting towers. 2nd, in case of our having to fall back from Attock, we must either destroy the bridge ourselves, or leave it to the enemy to do so. The bridge on the Khairabad side would require to be covered by an outwork, which should probably be considered in dealing with the cost of a bridge.

As to Permanence, with a known flood of 92 feet, there is no room for ties to limit vibration vertically; we can only obtain this to a small extent by deep trussed railings; and for lateral vibration, the effect of storms, if ties are to be applied, it must be by lengthening the piers, and increasing greatly the cost. The risk of accidents from the march of troops, &c., is also always considerable, and from high winds at Attock, it would be serious even with lengthened piers and ties. Last season the bridge of boats was carried away by being forced up the stream against the strong current, by the violence of a storm; of course the narrower the

bridge and the larger the spans, the weaker it is to resist this. The maintenance of a roadway, and an iron structure to be protected from the weather, would be heavy items, though the actual amount can only be calculated when a bridge is designed, but without doubt, it will not be less than equivalent to the renewal of the whole superstructure, *i. e*, chains, roadway, &c., once in 30 years. For the cheapest bridge at the lower site, the estimate is Rs. 13,50,000, of this the iron-work and roadway would be about 12 lacs, or Rs. 40,000 annually for cost of maintenance; and this I consider low.

Of the uncertain existence of Suspension bridges, it is only necessary to refer to the constant accidents occurring. Scarcely a year passes that we do not hear of the fall of one, in spite of all the modern precautions and improvements.

A Tubular bridge at the upper site, would not be open to so many objections as a Suspension, either as to its military bearing or permanence, but it still would be open like the other to destruction by floods, and in case of our having to fall back.

With such a torrent as the Indus, there must be great difficulties to contend with in all schemes for passing on, or over it, and I have endeavoured to the best of my ability to state them in detail; but in the end, the real crowning objection to all schemes of the kind, is the extraordinary floods and the uncertainty as to their limits; we may theorize and argue, and fix for ourselves imaginary limits, but while the cause is such as is known in this case, and there is no other outlet within reasonable limit for the water, such an amount of real danger exists, as I think no Government would like to risk, if any other means was available of accomplishing the same object, avoiding that risk.

III. The last means of improving the passage is by passing under the bed by a Tunnel.

This scheme was first submitted by me in 1859, and the following is an extract from my Report of that year:—

"The banks of the Indus at Attock are of a compact slate rock, and this also extends across the bed; the rock is easily worked, and apparently not broken up by any great fissures which might endanger the work. In fact the situation is most favorable for a tunnel, and such a work meets all our difficulties. The floods and velocity of the river cease to be matters to be taken into account further than placing the entrances well beyond

all risk. The military objections to an exposed bridge within reach of the cover of the hills disappear, and we secure a safe concealed means of crossing with every facility of closing it against an enemy without being forced to destroy or injure an important and expensive work. Once completed we have a permanent work available for the passage of railway or any other traffic, and free from the expense and wear and tear of any bridge or similar structure The expense and difficulty attending the obtaining from Europe of the materials for a bridge, and the machinery for erection, which after use for the one purpose become almost valueless, are all avoided; and we only require the ordinary labor of the country, or our own Sappers and Miners.

The dangers and difficulties and expense of the Thames Tunnel are likely to occur to all, but we must remember that this work was carried through the loam and silt of the bed of the river, or the upper part of the London clay; while here we have a solid compact rock to deal with, and run no risk from the principal difficulties that beset the Engineer of the Thames Tunnel.

I will now proceed to consider the details of the scheme. The bed of the river has been carefully sounded and examined, and the detail is shown in the accompanying sections; the deepest part of the river is under the right bank, here I have reached the rock at two points at depths of 28 feet and 31 feet 4 inches; but at an intermediate point between them, I could not make sure of being on rock at 34 feet 8 inches. In the stream under the left bank I could not get a rod down, as the bed is of large shingle; but I think we have sufficient data to show that the rock is at no point 40 feet under the low cold weather surface of the river; and allowing a safe thickness of rock between the roof of the tunnel and bed of the river, I fix the upper level of the excavation at 60 feet under low water mark. The dimensions I purpose for the tunnel inside are 24 feet wide by 20 feet in height, and a lining under the river of brick masonry 2 feet thick. This places the foundation level of the roadway 82 feet under the low water level, and placing the entrances 100 feet above this level for safety, we have 182 feet to descend and ascend.

The grade I purpose is 1 in 20; this is rather steep for railway traffic, but offers no difficulties to ordinary traffic, and I think we ought not to sacrifice largely in present expense, to provide for a probability only, which I consider a Railway to Peshawur to be.

The width of the river bed at the point I have selected for the tunnel is 1,215 feet, and this portion I propose should be nearly horizontal, having only an inclination sufficient for drainage towards the Attock bank. It would be more convenient, as the deepest channel is on the right bank, to have the inclination to this side, but I think it important that all the works connected with the tunnel should be on the Attock side under the protection of the fort.

The ascending grades commence from each bank of the river, and the height, 182 feet on the right bank, gives a distance of 3,640; and for 186 on the left bank (allowing a fall of 4 feet for the drainage) we have a distance of 3,720 feet; but deducting from these distances 660 and 700 feet, respectively, for open cutting, we get for the tunnel, 2,980 and 3,020 feet, or a total length of tunnel of 7,215 feet.

I propose to line the tunnel with brick masonry 2 feet thick under the river, and with masonry $1\frac{1}{2}$ feet thick from the bottom of the ascent up to the low water level, or for 1,640 feet on the right bank and 1,720 feet on the left; beyond this I think the lining may be dispensed with on the left bank or Attock side, and on the Khariabad side as far as the rock extends, and for this I have estimated; in the clay on the Khariabad side of course the lining must be continued.

The Drainage I have provided for by a culvert 3 feet span under the centre of the road, with suitable openings for the admission of the surface drainage of the open cutting, and for any percolation in the body of the tunnel. This culvert terminates in a well at the bottom of a shaft on the Attock side, and I propose to provide a ten-horse power pumping engine for the purpose of raising the water.

The Ventilation I propose to effect by means of ten shafts, 9 feet diameter, which will also be used as working shafts during construction. These shafts are 600 feet apart, except under the river, where the distance between the shafts on each bank is 1,580 feet. I have given the diameter of the shafts as 9 feet; this is the case with all the shafts but the one to be used for the pumps, &c., which is increased to 10 feet. These shafts are lined throughout with 1 foot thick of brick masonry, and where situated within the influence of the river flood, are carried up in massy columns formed as cut-waters on the up river side; the tops of the shafts are covered with iron gratings to prevent accidents from stones or other substances falling down them.

In the cold weather the ventilation will be very active, but in the hot season when the temperature in the tunnel will be generally lower than the external air, it may be necessary to apply artificial means; and this is provided for by a Steam Jet in the Pumping Shaft, and by gas burners in the others.

The Lighting I propose to effect by means of Oil Gas, manufactured on the spot and distributed to lamps placed at intervals of 25 feet. In general the lighting of every alternate lamp will be found sufficient."

In consequence of that report the sum of Rs. 10,000 was sanctioned to enable a trial drift to be commenced, and on the 12th March 1860, the sinking of shafts was begun by the Pioneer Regiment, which was placed at my disposal for the purpose.

When the shafts were sunk, it was found that pieces of rock were constantly becoming detached and falling down, endangering the workmen; this necessitated the lining the shafts at once; which though part of the estimate of the completed tunnel, was not contemplated in the first experiment. When the river rose in June, the leakage through the upper rock, at the west shaft, became more than means could meet, and necessitated a suspension of work for some months on that shaft, though endeavours were still continued to keep down the water.

In January 1861, finding that the original grant was likely to be exceeded, I reported at once, and a second amount, Rs. 10,770 was sanctioned. It included a horse-jin for raising water from the west shaft, (which was our great difficulty). Delay arose in the supply of the necessary machinery from Roorkee, and again work was stopped from May to November 1861, while great expense was incurred on temporary expedients to supply the place of the horse-jin; a heavy slip in the east gallery also occurred, and that, with the increase of water, caused a suspension of work on this side also for nearly three months. Again, in the hot weather of 1862, the main shaft of the horse-jin, (which had been made of cast, instead of wrought-iron, as I intended,) gave way and stopped work, the machine being fully up to the duty when in order.

The cost of the drift, Rs. 59,300, inclusive of working pay to the Sappers and Pioneers, having much exceeded the first rough estimate, led to the inference that the estimate for the tunnel would be found equally insufficient, and Government decided upon a suspension of the work until the matter could be thoroughly investigated.

My original estimate, made before ground was broken, was necessarily very rough; and as stated in my report, the actual probable cost could not be definitely fixed until the gallery was carried under the deep water channel of the river, and until the true cost of the machinery to be obtained from Europe was ascertained.

Work on the galleries was stopped in November last, when only 258 feet remained to complete the junction across the river.

The work done is as follows :

			cubic feet.
Excavation in rock under ground,	..	..	100,684
Excavation of rock above ground,	..	..	6,090

MASONRY.

Rubble under ground,	..	..	..	13,200
„ above „	..	..	..	18,262
Brick under „	..	..	..	9,876

Rating off the masonry and work above ground at the estimated rates, we get the real cost of the under ground excavation at Rs. 50·68 per 100 cubic feet, which, deducting the value of the plant on the ground, is reduced 41·08 Rs.; or if executed by coolies in the ordinary way, instead of by Sappers, to Rs. 38·56.

The galleries from first to last have cost from 30 to 40 Rs. per foot run, or about from 120 to 160 Rs. per 100 cubic feet, and the shafts Rs. 18 per 100.

				Square feet.
Now the area of the gallery was, ..	..	..	..	25
The mean of the shafts,	..	..	..	104
And the tunnel will be,	..	..	..	560

The cost of galleries was therefore about eight times the cost of shafts, and the areas as 1 to 4. The tunnel is more than four times the area of the shaft; in the same proportion, it ought to cost about 2-8 per 100, or Rs. 25 per 1,000. But of course this is too low, as material has to be raised, and there is more expense of stores, &c., &c. It is the cost of mining which is so much reduced. But we, I think, are perfectly safe in saying that as the

Galleries cost,	...	...	...	...	150 per 100
The shafts, ...	...	...	...	...	18 „
The tunnel will not exceed half that, or,			...	...	9 „

and this includes every charge. With the steam engine for pumping,

and even with horse-jins until it arrives, and with well organized establishments of all kinds, exactly suited to our requirements, (now well known,) I do not believe the work will cost half these rates.

To conclude this part of the subject, I will compare these rates with the cost of work in England.

The only work of the kind of which I have full details is Blechingly tunnel, on the South Coast Railway, 24 feet wide, and 21 feet high, through sandstone rock, shale, and weld clay, with considerable quantity of water. Total cost per yard run £71-18-7, say Rs. 719.

The cost of the drift and shafts together, was at the rate of Rs. 19·5 per 100 cubic feet, against our rate of Rs. 38 56.

The main excavation of Blechingly tunnel cost 6·1 per 100. Drift and shafts, 19 5. Apply to our rate, 38·56, the same rule, as 6·1 is to 19·5, we get 12·00 per 100. This should, I think, give confidence in the above calculations of rates.

The original estimate for the tunnel submitted by me, was Rs. 5,18,952, but after the galleries had been commenced, I made use of the data then obtained, and raised the amount to 6 lacs; the machinery still remaining an uncertain item.

Colonel Taylor submitted an estimate for an enlarged tunnel with reduced gradients or benches in approaches, but this when reduced to the original project, amounted to about 10 lacs.

In the estimate I now submit, I have adopted Colonel Taylor's rates in every case, except where my own deductions from the experience of the drift, led me to think he had estimated too low, or where other known rates exist. The machinery in his estimate, is of course equally imperfect with that of my first estimate, and in this case, I have substituted the tenders of firms at home.

I adopt Colonel Taylor's rates in preference to exercising my own judgment, as I know, however much we may endeavour to guard against it, yet when the value of a scheme is to be judged entirely by cost, there is a tendency in the projector to pinch and cut down, and at least to run an estimate very close. Even the estimate of one favorable to the scheme would be liable to the same fault, but in Colonel Taylor's I have that of an officer who has always opposed the scheme, and entertains ideas of its great costliness, as compared with a bridge.

The estimate I now submit amounts to Rs. 10,44,076·379, and to shew

how this tallies with the cost of tunneling at home, I annex the cost of some of the principal tunnels in England.

		£	s.	d.
Blechingly tunnel, blue clay, shale, and sandstone rock,	per yard.	71	18	7
Saltwood, middle beds of lower green sand (water,)	„	118	0	0
Meistham, chalk, ...	„	63	0	0
Clayton, chalk and sandstone, ...	„	57	0	0
Edinburgh and Dalkeith, clay, ...	„	20	0	0
Leeds, shale, coal measures and rock, ...	„	25	0	0
Kilsby, ...	„	125	0	0
North Shields, ...	„	16	10	0
Royston, red sandstone and bind, ...	„	50	0	0
Claycross, ...	„	100	0	0
Mean of 10, ...		640	0	0
Indus tunnel, estimate now submitted, Rupees, ...		10,44,076·379		
Rate, per yard run, ...		435		

The width of the above tunnels is stated to be from 24 to 30 feet, and the height the same, while the Indus is 24 × 20. Our saving is in masonry.

The rates I have adopted are as follows:—

In excavation under river, Colonel Taylor's rate of, ..	100	per 1,000
In approaches, rock „ „ „	80	„
In approaches, clay „ „ „	30	„
Footway and in shafts, I have taken a higher rate than Col. Taylor, as the data of the drift done shews this should be so, Colonel Taylor takes 80, I take, ...	150	„
Open cutting, ...	16	„
Clearing ground, „	10	„
Masonry under ground rubble, } Colonel Taylor's rates,..	16	„
„ „ „ brick,	35	„

Shoreing, I have made Rs. 5 per foot, instead of 3, by Colonel Taylor. Drift gallery under river, Rs. 40 per foot run; on descent, Rs 20; in excess of Colonel Taylor's rates, though a part of this is in clay, and the distances between shafts short.

Pumping, as per separate estimate.

The Lighting is fully provided for in the rates and not taken separately.

I will now endeavour to reply to the objections made to the details of the scheme, and add any further explanation that may seem necessary beyond that given in my original report.

The site selected is not the narrowest part of the river, but it is that where the appearance of the rock promises best for continuity and soundness; where the bed is shallowest, and least disturbed (being above the

neck of the funnel) and is favorably situated as regards access from the Trunk Road. I believe rock would be found all across the river at the fort, the only accessible point where saving in width could be effected, but here the depth of the river is much greater, so that the length of approaches would be considerably increased, and the depth of the shafts, and consequently cost of all the work be much greater. Mr. Medlicott, in his report, expresses his opinion that the site in all respects is the best, and an inspection of the accompanying plan will enable a judgment to be formed on this point.

The width and gradient of the approaches have been objected to.

As to width, 18 feet roadway and 6 feet footpath, or a total of 24 feet is the size proposed; 18 feet is quite sufficient for the easy passing of two conveyances, and with a limited traffic such as that at Attock, what more can be required? but as this matter has been disposed of by the Supreme Government, I will not enter further on the subject.

With regard to the gradient, or slope of the approaches, as I have already shown, the amount of traffic is not heavy, the length of the ascent or descent is under three-quarters of a mile, and therefore no great pull upon the cattle. The grade of 1 in 20, is in modern days considered a little too steep for very fast traffic, but not so much so, for slow. The usual standard for roads in England, except in exceptional cases, is 1 in 30; but these exceptions, even on the first class mail roads, are common. On the London and Cambridge road, at Stamford hill, the inclinations on both sides is at 1 in 20. On the Chingford road, there are still slopes of 1 in 8 and 1 in 9. On the London and Chipping-ongar road at Wilcox Green, the inclination for a considerable distance is 1 in 20, and again at Chigwell Vicarage it is the same. On the London and Dover road, one of the most important roads in the kingdom; from Deptford to Blackheath, the slope is 1 in 17, at another place 1 in 14, at another 1 in 11, and again 1 in 14; at Shooter's Hill, 1 in 18; further on, 1 in 11, 1 in 16, and 1 in 13. In the greatest thoroughfare in the city of London, we have Holborn Hill, with slopes in some parts of 1 in $16\frac{1}{2}$; the same on Snow Hill. Surely this is enough to shew that there can be no serious objections to a gradient of 1 in 20 at Attock, with our very moderate traffic.

The following is the rate of inclination of a road, at which a carriage of any kind would descend of itself, for the different descriptions of

road covering. The calculations are from Sir John McNeil's experiments.

Broken stone surface laid on old flint road,	.. ..	1 in 34
Gravel road,	.. ..	1 in 15

and as the roadway of the tunnel is to be of gravel, the road is long within the limit when there would be even a pressure on the bullocks in descending.

There is no disputing that an easier gradient would be an improvement, but it is a simple matter of money; every reduction in the gradient increases the length of the tunnel, and not only adds most materially to the original cost, but to the permanent expenses, in lighting, &c., and I can only say, in my opinion the gradient is fully sufficient for the situation, and the demands of the traffic; and I support my opinion by shewing that steeper slopes were tolerated on the most important roads in England, when roads were all in all, and are now tolerated for what traffic remains.

There are a few points in my original report in which I have made modifications and these I will now note.

I originally proposed to line the tunnel throughout with brick masonry, but the fine quality of the stone in the gallery, has induced me to make the side walls of rubble masonry, using brick only in the arch overhead

The Steam Engine was erroneously put down as one of 10-horse power, I wrote shortly after submitting my report to correct it to one of 25, and further consideration and consultation with Mr. R. Napier, of Glasgow, has induced me to adopt two small engines of about 15-horse power each, with pumps, &c., complete. The advantages are economy, in only working a small engine instead of a large one, when one is sufficient; and second, always having one available, in case of one being out of order and under repair; while the cost of two small engines is little in excess of one. The specification and tenders for the machinery are all attached to the estimate.

For the Ventilation in each shaft I have provided a sunburner of 16 lights.

Regarding the details of the Gas Machinery, &c., the specification was prepared by me after visiting Frankfort-on-the-Maine, the last city in Europe in which oil gas was used, and getting every information from the engineer of the gas-work, who had been in charge when oil, resin, &c., were used. I had also communication with the principal gas engineers in

London, and consulted with the engineer who makes the tender, and adopted some improvements suggested by him; and I believe I have gone into the subject in full detail.

Regarding the Lighting I have only to add that one lamp at every 50 feet, as stated in the report, will fully light the tunnel (in broad streets at home the lamps are generally at 100 feet intervals) and that at night, the consumption of gas will be reduced to a minimum, by turning it down at the governor, so as simply to leave a glimmer

As it is quite within the limits of possibility that we might have to fall back from Attock for a time, I have provided a 12-inch siphon, to be built into the masonry of the west shaft at the level of the top of the rock, or about 25 feet above the cold weather level of the river; the pipe to be carried down the shaft to the level of the floor, and end in a short turn up the shaft; the pipe is provided with a valve, to prevent water entering during the ordinary rise, and there is also an air pump to exhaust the air, and put the siphon in action. This may appear an unnecessary precaution, and it is a point for Government to decide, but its cost is not great and I think it is worth adopting.

I may here state that the Tunnel entrances and the air shafts as estimated, are 100 feet above the cold weather level of the river; and though precautions might be taken to keep out even a higher flood than this, if due warning were given, still we must be prepared for the filling of the tunnel, by an extraordinary flood

In the Tunnel there is nothing to injure, and the only thing would be the removal of the water, through the siphon provided for filling the tunnel, or by the footways; the water would flow off as the river fell, to a level a little higher than that of the river, and in eighteen or twenty days the steam engines would remove the remainder.

In the present estimate I have provided a small footway on each side of the river, at a grade of 1 in 2, for the use of workpeople, instead of lowering and hoisting them up and down the shafts, which now is a serious item of cost. The path will also be available when the work is finished, for foot passengers to the Fort of Attock, and town of Khariabad; this footway I propose to make 8 feet × 10 feet.

To conclude the subject of the complete Tunnel, it only seems necessary to enter on the current expenses of the work. I annex a separate estimate of this in full detail, including all establishments, &c. It amounts to Rs.

15,966·45, and as the revenue of the ferry is at present Rs. 17,000, all Government stores, troops, &c., passing free; even allowing for no increase in traffic, the sum of Rs. 1,033·55, becomes a saving; and even if petroleum should fail, and oil be used, the cost would only be Rs. 23,529.

This estimate of current cost is a liberal one, and I think it is more than likely than on it considerable saving may be effected, principally in gas and fuel.

Agreeable to my instructions, I have endeavoured to go into the whole subject of the Indus passage and of the means of effecting it, as fully as possible; I have no doubt there is in this report a strong leaning in favor of my own project, but I trust I have still stated the whole case sufficiently, fully and fairly, to enable Government to decide in the matter.

ESTIMATE framed by Major A. Robertson, Superintending Engineer, of the probable cost of constructing a Tunnel under the river Indus, with approaches at a gradient of 1 in 20.

SPECIFICATION.

The Tunnel to be 24 feet wide and 20 feet high; to have a cart roadway 18 feet wide, covered with shingle metal 1 foot thick, and a footpath raised 1 foot above the cartway, and with a cut-stone curb on the outside; the footway to be covered with 6 inches of fine sifted shingle, rammed.

The Tunnel throughout to be lined with masonry, the side walls of selected stone from the excavation, and the arch overhead of brick, all laid in hydraulic mortar; the thickness of the lining to be 2 feet under the river bed, and $1\frac{1}{2}$ for the remainder of the tunnel.

A Culvert 3 feet wide and $1\frac{1}{2}$ deep, to run under the centre of the roadway throughout the tunnel, and to terminate in a well under the pumping shaft, to be excavated in the rock and arched over with masonry $1\frac{1}{2}$ foot thick, and through the clay to have an invert and side walls.

When the rock is sound there will be no invert to the tunnel, but through clay or unsound rock there will be an invert of stone from the excavation, laid in hydraulic mortar, $1\frac{1}{2}$ foot thick, except under the river where it will be 2 feet thick.

The Drainage from the open cutting at each end not to be carried down into the tunnel well, but discharged by a small tunnel 4 × 3 feet, leading out to the low ground from the mouth of the tunnel, where a suitable well and cross drain will be formed for the collection of the water; this outlet or discharge tunnel will be closed by a trap of cast-iron with planed gun-metal faces, built into the masonry, and which while allowing the discharge of the surface drainage will prevent the entrance of water in case of a flood.

Air Shafts 9 feet internal diameter, lined with 1 foot thick of brick masonry, to be formed at intervals of 600 feet, except at the river section, where the interval is 1,515 feet; the shaft on the left bank, which is the pumping shaft, is 10 feet diameter instead of 9 feet.

Cast-iron curbs in 4 pieces, bolted together, and cast with recesses for the bonding in of the brick-work, to be provided for the junction of the brick lining of the air shaft with the arching of the tunnel.

The air shafts where situated within the influence of floods to be carried up in massive rubble masonry columns, formed as cut-waters on the upper side, as shewn in the detailed drawings accompanying, and to a height of 100 feet above the cold weather level of the river.

The air shafts to be covered with wrought-iron gratings and wire nettings to prevent accidents in the tunnel by substances dropping down; iron cramps and masonry blocks, as shewn in the drawings, to be provided for placing ladders to ascend the shafts for repairs or other purposes.

The shafts carried to any height to be provided with lighting conductors, iron rod 1½″ thick, and carried 8 feet above the top of the shaft, and, at least 10 feet down into the soil, and away from the masonry of the shafts.

The Tunnel under the river to have an inclination of 1 in 300 to the Attock side, for drainage, the ascents to commence from the banks on each side and to be at the rate of 1 in 20.

Two Pumping Engines with pit gear complete, as per separate specification, to be provided for keeping the tunnel clear of water, and a steam jet to be provided in the pumping shaft supplied from the engine boilers to promote ventilation.

A small donkey engine to supply the gas work with water, and also to drive the tools in the workshop, with pipes and shafting to be provided; also a turning lathe of 6 inches, and another of 12 inches with drilling, planing, and slotting machines, for repair of steam and gas machinery.

The Tunnel throughout to be lighted with Oil Gas manufactured on the spot. The gas machinery, as per separate specification and drawings, &c.

The Gas lamps to be fixed on iron brackets projecting from the side of the tunnel over the footway, the lamps to be provided at 25 feet intervals, but only each alternate lamp lighted, except on extraordinary occasions, this will be found amply sufficient for the clear lighting of the tunnel, gas to be laid on in the engine house, gas sheds, and quarters for the establishment.

In the 9 feet ventilating shafts, sunburners of 16 lights each, to be provided for ventilation.

The necessary governors, cocks, metres, &c., to be provided as per separate specification.

Engine house, gas sheds, and boiler sheds with iron roofs, and suitable quarters for the establishments to be provided; also a workshop, stores, and work godowns.

The culvert under the roadway to be provided with cast-iron man-holes built into the masonry with suitable frames, placed at 300 feet intervals, to admit of men going in to clean the culvert.

A Siphon 12 inches internal diameter to be provided for the purpose of filling the tunnel with water, in case of having to abandon it, or fall back from Attock.

The siphon to be carried down into the river 3 feet below the low water level on the right bank close to the masonry shaft, to be carried through the masonry at the level of the ground and down the shaft to the floor of the tunnel, where it is to terminate in an upper turn so as to point direct up the shaft, a valve of the ordinary conical seat construction, to be placed on the pipe 6 feet under the low water level of the river, and with a rod suitably supported carried up to a stage fixed in the shaft above the ordinary high flood level of the river. On the stage a suitable air pump to be placed with a pipe connecting it to the siphon, to exhaust the air when necessary and put the siphon in motion.

A small gas apparatus, as per separate specification, to be provided for the purpose of testing the various substances procurable and suitable for the manufacture of gas.

Jins to be provided for raising the material, water, &c., while work is in progress.

A small footway 8 feet wide and 10 feet high, at a grade of 2 to 1 to be formed on each side for the use of the workpeople, &c

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ABSTRACT FOR COMPLETE TUNNEL.

r ft.		
285·	Drift gallery under river, at Rs. 40, - - - - -	11,400·
4,700·	Rock in approaches, at Rs. 20, - - - - -	1,14,400·
1,020	Clay " " - - - - -	
c. ft.		
6,97,341·35	Rock excavation under river, at Rs. 100 per 1,000, -	69,734 135
28,14,351 54	" in approaches, at Rs 80 per 1,000, -	2,25,148 123
1,07,325 048	" in footway and shafts, at Rs 150 per 1,000, - - - - -	16,098 757
4,450	" in drainage tunnel, at Rs. 150 per 100,	6,675·
3,000·	Rock excavation, in discharge from open cutting, at Rs. 60 per 100, - - - -	1,800·
3,23,071·25	" in open cutting, at Rs. 16 per 1,000, -	5,169 140
50,263 800	Foundation in hard rock, at Rs. 16 per 1,000, - -	804 220
25,002·	" in clearing ground, at Rs. 10 per 1,000, -	250 020
56,032·	" in gas tanks, &c, at Rs 20 per 1,000, -	1,120 640
6,97,098·048	Excavation in clay under ground, at Rs 30 per 1,000,-	20,912·941
21,45,611·924	" in open cutting and embankment, at Rs. 3 8 per 1,000, - - - -	7,509·641
5,16,865·23	Rubble masonry under ground, at Rs. 16 per 100, -	82,698 436
1,97,020·797	" in retaining walls, &c., at Rs. 16 per 100, - - - -	28,643 327
3,064·	" in traps and doors, at 16 Rs per 100,	490·240
11,566·66	Brick and rubble masonry in entrances, at Rs. 20 per 100, - - - - - - - -	2,313·332
25,726·	Rubble masonry in houses, &c., at 16 Rs per 100, -	4,116·160
3,95,152 05	Brick " under ground, at Rs. 35 per 100, -	1,38,303 217
1,497 41	Timber in shafting, at Rs. 1 8 per cubic foot, - -	2,246·115
s. ft.		
1,922·	Roofing in main building, at Rs 30 per 100, - -	576·600
880·	" in verandahs, at Rs. 22 per 100, - - -	193 600
1,520·	" rough, at Rs. 15 per 100, - - - -	228·
320·	Flooring slate slab, at Rs. 24 per 100, - - -	76·800
764·	350 doors and windows, glass and pannelled, at Rs. 1 per foot, - - - - - - -	350·
	414 battens, at Rs. 0-12-0, - - - - - - -	310·500
c. ft.		
1,49,711·25	Shingle metal, at Rs. 15 per 1,000, - - - -	2,895·018
14,430.	Cut stone curb, at Rs. 12 per 100, - - - -	1,731·600
lbs.		
2,000.	Cast-iron, - - - - - - - - - -	250·

ABSTRACT FOR COMPLETE TUNNEL (*Continued*).

lbs.		
3,535·379	Wrought iron, at Rs 22 per 100, - - - - -	777·783
	Godown and workshops, temporary, - - - - -	3,000·
	Overseers' quarters, „ - - - - -	1,500·
	Engineers' quarters, permanent,- - - - -	4,000·
	Machinery, as per separate estimate, - - - - -	1,29,895·
ft.		
7,200	Shoreing, at Rs 5, - - - - - - - - -	36,000·
	Pumping for 5 years, at Rs. 4,470, - - - - -	22,350·
c. ft.		
4,160·	Flooring footway, at Rs. 20 per 100, - - - - -	832 000
r. ft.		
180·	Ladders, at Rs. 2, - - - - - - - -	360·
	Clearing out water, re-laying rails, putting machinery in order, &c., - - - - - -	4,000·
	Total Rupees, - - -	9,49,160 345
	Contingencies 10 per cent, - -	94,916 034
	Grand Total Rupees, -	10,44,076 379

A. ROBERTSON, MAJOR,
Superintending Engineer.

No. LVI.

MILITARY BRIDGES.

Some Remarks on Military Bridges. BY LIEUT.-COL. A. COWPER, R.E.

IN this paper it is proposed to discuss in as succinct and practical a manner as possible the principles and practice of Military Bridge making, and thence deduce the constructive details which will subserve most completely all these conditions.

An instructive experiment in connection with this subject was made in the latter part of 1859 at Poona, under the orders of Sir Hugh Rose, with the Blanshard Pontoons, and the result is shown in the 6th paragraph of the report, which was submitted in consequence by the writer, who then Commanded the Bombay Sappers and Miners by whom the bridge was laid, and which report is below set down at length.

To the Quarter-Master General of the Army.

SIR,—In compliance with the wish of His Excellency Sir William Mansfield, that I would state the comparative merits of the Austrian and English systems of Pontooning, as represented by Byrago and Blanshard, I shall have the honor of describing each system and its capabilities in as few words as I am able, and then of estimating each by the standard of practical adaptability to the requirements of actual service generally.

ENGLISH OR BLANSHARD'S SYSTEM.—The English system at present in use is one instituted by Colonel Blanshard of the Royal Engineers, as an improvement upon Pasley's. It consists, like every other Military Bridge, of supports and superstructure. The former are water-tight tin or copper cylinders with curved ends, and are called Pontoons. The latter consists

of beams, which extend from one pontoon to the other, and planking, which is placed across the beams; these, in professional phraseology, being termed Balks and Chesses. It is not necessary in this brief sketch that I should proceed to give details that refer to points of internal economy, regarding the suitability of which to their own system there is no question, but that I should rather draw attention to those points of general efficiency and usefulness on which the merits of the two systems must stand or fall. I will, therefore, omit the minutiæ that are laid down in the Drill Book used at Chatham, and proceed first with a brief outline of Blanshard's system, and afterwards of Byrago's.

Easy adaptation to the beds and banks of every variety of stream; stability and firmness as a bridge during the passage of heavy Artillery and Cavalry, strength and durability as an article of Army equipment, and, lastly, portability in transit, seem to constitute the main, and indeed the essential, elements of a good Pontoon system. I have already (in a previous letter) drawn attention to the floating supports of the Blanshard Bridge, which, as I shall hereafter show, affect its adaptability to beds and banks of a certain character, no less than its firmness as a bridge under the passage of Artillery, and its durability as an article of Army equipment. It now only remains for me to describe its portability; any advantage that it may gain in this particular is met by sacrifices of far greater importance than are consistent with efficiency.

A tin Cylindrical Pontoon weighs 565 lbs, and its buoyancy is 7,369 lbs. The bridge may be made capable of bearing a greater or less amount of weight by adjusting the Pontoons close together, or wider apart, as follows:—

For Siege Artillery, ..	..	8 feet	2 inches	apart	from centre	to centre.
For Light Artillery, ..	..	10 „	4 „	„	„	„
For Cavalry and Infantry,	..	12 „	6 „	„	„	„

The Balks are about 14 feet long by $4\frac{1}{2}$ inches deep by 3 inches broad.
The Chesses are of deal planking about $1\frac{1}{2}$ inches thick.

Such a bridge ought to be lighter than any other, owing to the slight dimensions of the scantling; but, as I have just observed, the advantage that is gained in that respect is more than counterbalanced by the sacrifice of firmness in the roadway, and want of durability in the materials. The system, too, of obtaining buoyancy by bringing the Pontoons close together is open to the objection that it obstructs the current of the river, and ren-

ders the anchors liable to drag, or the cables to snap, and thus endangers the whole bridge.

A bridge, too, which depends entirely upon floating supports is, of course, useless in all cases (and they are of frequent occurrence in India) when these supports cannot be applied throughout from bank to bank. Where, moreover, the banks of a river are high and precipitous, the water shallow, the bed of the river unfavorable to anchor in, or where the stream partakes of the nature of a torrent, Blanshard's Bridge could not be used; neither could it be constructed where the obstacle is of a dry nature, such as restoring the broken arch of a bridge, passage of a dry, muddy nullah, marshy ground, &c., &c. We are, therefore, limited in its application to those places where the section admits of the use of floating supports throughout, and where the banks permit of the approaches being sloped with but little trouble at an easy gradient to the level of the roadway; consequently, the situations where it can be used are so restricted as to be very seldom available in the presence of an enemy, and even when such favorable spots are met with, it can only be considered an Infantry Bridge, for we have proof that the passage of Artillery and Cavalry, but more especially of the following of an Indian Army, would, even under the greatest care and best arrangements, disable it; so slight is the construction and liable to injury of both the scantling and the pontoons themselves. I am not aware of any instance where this bridge has been used on actual service for the passage of Artillery and Cavalry, but in the experiment made towards the end of 1859 at Poona, under His Excellency Sir Hugh Rose's orders, we had ample proof in corroboration of similar examples at home and elsewhere, how, even under the most favorable circumstances, the oscillation of the whole bridge and the deflection of the roadway frightened the horses and led to a serious accident, in which gun and limber, with team and drivers, were plunged into the river; fortunately, the water was not more than 4 or 5 feet deep in the part where the accident occurred, otherwise several lives might have been lost. The general impression of every experienced observer present was, I believe, that such a bridge was, as I have before observed, only fit for Infantry, and as such quite inapplicable to the purposes of general service in the field. To depend upon it for effecting a retirement across the most insignificant stream in the face of an enemy, on a far smaller scale than that effected the other day by the Austrians in presence of the French forces at Solfe-

rino, would be utter folly, as the least crowding or confusion could not fail to be attended by, at least, the interruption of the communication across the river, and, probably, heavy disaster in consequence.

The violent oscillation of the whole bridge I attribute entirely to the character of the light floating supports, and the great deflection of the roadway under a team of horses and a 6-pounder gun to that cause, as well as the flimsy planking and superstructure generally. I am convinced that the first evil will always result more or less from the exclusive employment of floating supports, even were those supports firmer than the copper pontoons are; and I can see no remedy for this evil to be compared with the superior principle of combined fixed and floating supports embraced by the Byrago system, to which I shall now have the honor of adverting.

Austrian or Byrago's System.—In considering this system it is difficult to say which is the most to be admired,—the principles on which it is devised, or the constructive ability shown in the details. The supports are of two kinds, fixed and floating; the first called trestles, and the latter pontoons, so that, according to the nature of the obstacle, a bridge can be made, capable of bearing Siege Artillery, either of fixed or floating supports, or of a mixture of the two. It follows from this that double supports are carried with each equipage, and that about half are used and half in reserve in every formation of bridge.

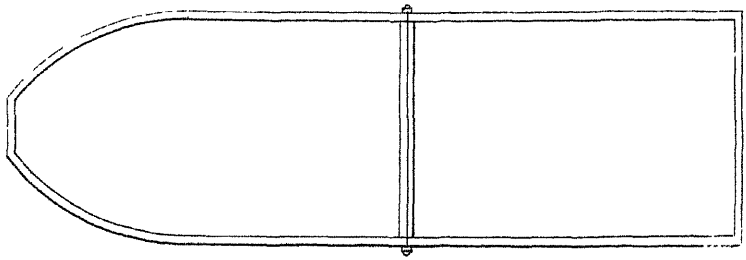
Austrian Pontoons.—The Austrian Pontoons are of wood, undecked, and are of two shapes, shown in the plan, called a Bow and Middle-piece. The weight of each is about 6 cwts. and buoyancy 9,800 ℔s. These can be used as row or sailing boats, and on any river, however strong the current. They are provided with canvas bulwarks to be used in rough water, so that the waves cannot beat in.

Any number of these Pontoons can be coupled or linked together by means of iron fastenings, so as to give great buoyancy for flying bridges, and ferry or sailing boats. A boat of 5 Pontoons linked together, 2 bow-pieces at the ends, and 3 middle-pieces in the centre, would form a well proportioned double-ended boat of about 60 feet long, and 20 tons burden; and if two of these were lashed side by side, a vessel of 40 tons extreme burden would be formed. As supports to an ordinary bridge, two pieces, a bow, and middle-piece linked together, would be sufficient for the passage of Siege Artillery, and would form no greater obstacle to the stream than

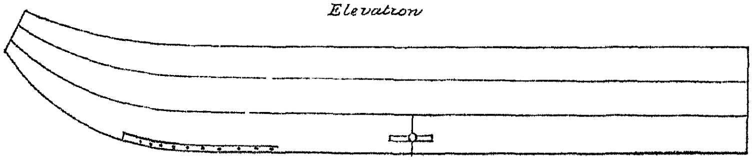
MILITARY BRIDGES.

Austrian Pontoons.

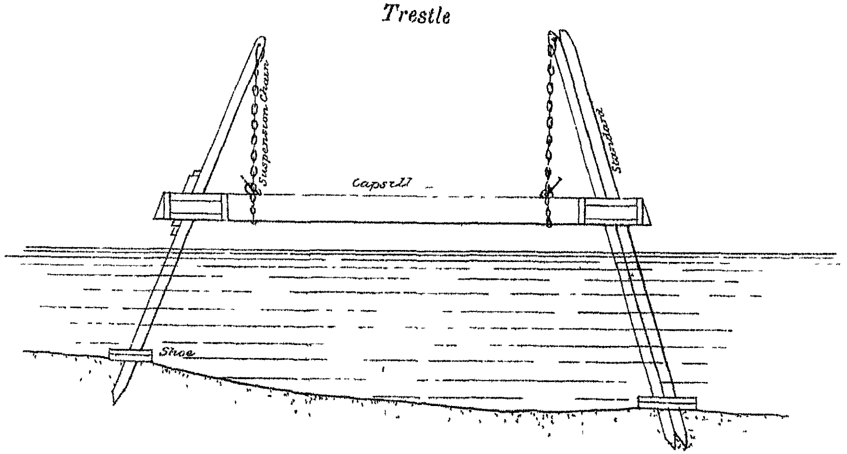
Plan



Elevation



Trestle



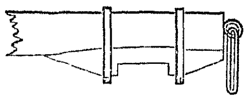
one pontoon piece. By having the floating supports in pieces a great many most important advantages have been gained. They are very portable, easily loaded and unloaded on and off the waggons, and can be fastened together one behind the other, so as to give the required buoyancy in the water without obstructing the current of the river.

Byrago's fixed Supports (Trestles).—The trestles are a peculiarly valuable feature in this system, and more especially with reference to India. A tracing of one is given in the plan, with the names of its component parts written opposite each.

A complete trestle consists of a capsill, on which the ends of balks for the roadway rest, and this capsill is supported at the requisite level by means of two standards, which pass through mortices, at the ends of the capsill. Two suspension chains connect the standard and capsill, and keep them in their relative places. These trestles are employed wherever they are preferable to the pontoons, such as, where the roadway of the bridge is required to be at some considerable height above the water level, in shallow or rocky streams, dry nullahs at broken arches of bridges, in torrents, &c. Wherever practicable, they should be used, instead of floating supports, as their capacity for carrying weights is nearly unlimited; they present very little obstruction to the current,—allow of no vibration, whether vertical or lateral, during the passage of material and troops,—are but little liable to get out of order, and easily repaired if they do,—do not require any anchors, and are not liable to shift their place and injure the stability of the bridge by altering its adjustment,—and are much lighter and more handy than pontoons of the requisite buoyancy. The standards are 8, 12, 16, and 20 feet long, so as to be adjusted to any depth of water and to any obstacle. They are provided with shoes, as shown in the plan, to be used in soft ground. Their points are shod with iron as a protection.

Balks.—The balks of the system are of large size, being 23 feet long 5 inches broad and 6 inches deep. The breaking weight of each is about 3 tons, and effective strength $1\frac{1}{2}$ tons. Their great strength and size add much to the practical value of the bridge for the transport of heavy and Siege Artillery and Cavalry, which latter could cross the bridge in sections of three's. Every bridge should be capable of transporting Siege Artillery, as it is the most difficult of all arms to transit. Infantry can almost always effect their own passage over obstacles in some manner or other, and Cavalry can surmount many obstacles unaided. The ends

of these balks are half mortised, as shown in the margin, by means of



which they can be built up together, so as to form bridges of 40 feet span, or upwards, without intermediate supports, capable of carrying heavy Artillery. They are provided with rings at the ends for handling them, and by means of ropes passed through these they can be dragged on board of pontoons from the shore, &c. The weight of one balk is 150 lbs.

Chesses.—The Chesses or planking of the superstructure are 10 feet 7 inches long by 11 inches broad by $1\frac{1}{2}$ inches thick. They can be used indifferently either end or either side up, so that no mistake can possibly occur either by unskilfulness in the men, or from their being laid in the dark.

Forming the Bridge—Prior to forming the bridge, a section of the obstacle to be passed is first made, and the nature of the supports to be employed is determined. The trestles enable us to employ fixed supports, until the roadway is 17 feet above the river's bed, pontoons being employed in deeper water than that. In shallow water and on dry ground the trestles can be put together at their proper places, and raised by turning them over on the points of the standards by hand. In deep water they can be put together on pontoons, and slid over the side into their proper places. Those portions of the bridge which have floating supports are boomed or thrust out from the shore, or from the last trestle, as the case may be, in succession, in very much the same manner as the English pontoons are boomed out. The bridge can be broken up and reformed at any other place by packing the superstructure on the pontoons, either singly or in rafts, according to the proposed locality either up stream or down stream.

Application of both systems to India—In India rivers are the chief obstacle which would arrest the march of an Army. They may be considered as torrents at certain seasons of the year, and, as a necessary consequence, their section at other times generally presents a considerable breadth of water, banks precipitous,* and a stony or rocky bed, the slope from the water's edge to the centre being very gradual. The seasons of flood differ throughout India; the floods take place in the hot weather in those rivers which rise in snowy mountains, in the rains in those rivers which are under the influence of the South-West monsoon, which never

* This is not the case with the rivers of Bengal, Hindoostan, or the Punjab, except in the upper portions of their course. Below, the banks are low, being often inundated in the rainy season, and the beds sandy.—[ED].

fails, and in the cold weather in those under the North-East monsoon, which sometimes fails. A system therefore, to be properly adapted to India must suit these three different kinds of rivers, both when in flood and when the water in them is low.

The character of all these rivers at low-water demands that the supports should be chiefly, if not entirely, trestles, and when in flood, in the great majority of cases, trestles would also have to be used. The only case where floating supports would be required throughout would be, as far as I am able to judge, chiefly during the flood of the first class of rivers, or, in other words, these kinds of supports would only be required in one case out of six. The rivers in India and the Punjaub belonging to the first class might be crossed by floating supports only, but the second and third class of rivers would almost always demand fixed supports. The Southern Mahratta Country and the Madras Presidency afford good specimens of the second and third class of Indian rivers respectively. To recapitulate therefore, and to show the relative merits of the two systems in a tabular form, the following statement is drawn up. The guiding points for determination have been selected from the English "Aide Memoire," page 173, both as setting forth the properties of a bridge very clearly, and being drawn up by the Royal Engineers must be considered as perfectly just to the English system. The numerical value opposite each item has been arbitrarily fixed by me. A consideration of these values will, I think, show that they have been carefully estimated. :—

Qualities of Bridges.	Value.	Blanshard's	Byrago's	Remarks
1 General applicability, ...	20	8	20	If available as rafts, boats, &c., besides serving as a bridge.
2 Simplicity of character,	9	9	7	So that its management may be easily learnt by all Troops.
3 Capability of rapid construction,	8	8	6	
4 Security from destruction by an enemy,	6	4	6	From peculiarity of construction in detail, or from its general arrangement.
5 Ultimate buoyancy, ...	9	5	9	
6 Stability,...	8	4	8	
7 Height of superstructure above water,	6	3	6	With reference to the section of the floating supports.

Qualities of Bridges.	Value.	Blanshard's.	Byrago's	Remarks.
8 Ease of management and motion in water,	8	7	8	Implying also lightness and suitability for speed in rowing as a raft boat, &c , capability of movement as a quadrant of conversion.
9 Facility of detail, construction, and repair,	12	10	12	As requiring only such material and workmanship as are likely to be at hand.
10 Security from destruction by natural causes,	5	2	5	Strength to oppose the violent action of the wind or water, &c.
11 Cost and expenses, ...	9	9	9	Including transport, &c.
Total, ...	100	69	96	

That is, the Austrian system fulfils 96 per cent. of all the qualities necessary to a Bridge system, and the English only fulfils 69. I would beg particularly to request attention to this point, and that the arbitrary values fixed by me may be more particularly scrutinized. I feel, however, certain that if the values I have given be over-ruled, and others fixed by the authorities, the result will still be very much the same as I have given it.

The above, however, by no means gives the full superiority of the Austrian system. The details of the construction, as well as the principles of the bridge, must be taken into consideration. In the English system these details are more particularly faulty, as will be seen from the following statement of some few of the items:—

Items.	English.	Austrian.
1. *Method of securing the shore ends of the Bridge* (The stability of the whole construction depends upon the ends being perfectly firm and fixed on the rivers' banks.)	No established method They must be got up from materials on the spot. A very unsatisfactory arrangement.	Is provided with very strong and complete shore fastenings, called Landsills, which are picketed and wedged down, and on which the balks rest.
	Balks.	
2. *Fastening of the superstructure.*	Are fastened by means of pins between cleats Owing to warping and shrinking of wood, these fastenings are very difficult and tedious to adjust.	Are fixed into their rests by being half mortised at the ends. No difficulty can, consequently, ever arise in adjusting them.

Items.	English.	Austrian.
	Chesses.	
	Are racked down to the saddles at 12′ apart. Require great care in the laying, owing to the somewhat intricate arrangement of the cleats, and would be difficult to lay at night, and liable to mistakes at all times when expedition was required, and skilled pontooners not procurable.	Are racked down throughout to the balks, whereby the whole superstructure affords mutual support, and cannot be easily displaced by an accident, by rough water or heavy traffic.
3. *Transport of the Train.*	Balks are put on the waggons, and then Chesses. The centre of gravity of the load is very high, and the waggons unstable. They are also very cumbrous, and unwieldy in turning, &c.	Chesses first packed, then Balks, by which means they are unloaded in their proper order for forming the bridge, centre of gravity low, and waggons very stable; can turn on their own grounds, and are very handy. Gross weight less than Blanshard.
4. *Pontoons.*	Of tin or copper, very liable to leak and get out of order, and are very fragile. Their form being circular, is extremely unstable. Weight 570 lbs., buoyancy 7,369.	Are of wood, strongly made, and only liable to leak from the land carriage in the sun. Section extremely stable. Weight 650lbs., buoyancy 9,800.

The weight per foot run of the English Bridge is 209, and the Austrian 179 lbs., for the passage of siege Artillery in both cases. For light Artillery 164 and 146, respectively, and for Infantry 4 deep, 136 and 115, showing a large saving of portability in each case in favor of the Austrian system. I am, therefore, of opinion that the Austrian system is in every respect more adapted to the present state of the art of war and operations in presence of an enemy, and more especially to our Indian empire.

I have, &c.,

A. Cowper, Captain.

The writer having visited England since the date of the above report, has been led to consider the various details connected with the main objects

of a good Pontoon system, and in the course of his enquiries, the improvements detailed below upon the systems referred to have suggested themselves, and they are now brought forward for the purpose of eliciting discussion.

The subject will be divided under the following heads :—

Necessity of a Bridge Train to accompany an Army.

Requisites of an efficient Bridge Train.

Composition.

Selection of Bridge Sites.

Preparations and details of the Passage.

Carriage of the Train and distribution of materials.

Construction and details of a perfect Bridge System which fulfils all the necessary conditions.

Necessity of a Bridge Train to accompany an Army.—In Military operations, the chief and most serious obstacles to the march of an Army are the rivers and water-courses of all kinds which are met with. The positions of the permanent bridges over these obstacles are perfectly well known to the enemy, and being generally situated on the large lines of made road, are consequently not available for our use when within the circle of the enemy's activity. Neither can we place any reliance on 'bridges of circumstance' to cross these obstacles, owing to the fact that their construction can seldom be effected except under very favorable circumstances as regards materials and at a considerable expenditure of time.

It is rendered necessary therefore by strategetical reasons that every large body of troops engaged in important expeditions should be accompanied by a Military Bridge system, or Pontoon Train, to ensure its efficiency as affording the best, and indeed only, means of passing these obstacles.

Requisites of an efficient Bridge Train.—The Bridge Train generally proceeds with the Infantry, under whose protection it is laid; when the time arrives for the formation of the bridge, it must proceed at a rapid pace to the front, carrying on its waggons the men who are to lay it. On arrival at the river the transit of the covering party is effected by means of row boats, which are next employed on laying and serving the bridge. After the passage of the Army and following, it has to regain its position by forced marches to the front.

It follows therefore that a perfect Military Bridge system should com-

bine mobility to traverse difficult ground with ease, with quick means to pass armies over considerable rivers. There is at present no Bridge system in existence which perfectly fulfils both these conditions.

Composition of a Bridge System.—Every Bridge system is composed of superstructure and supports, the latter being both fixed and floating.

Superstructure.—To diminish weight and transport and consequently increase the bearing power of the supports, as well as to diminish oscillation, the roadway should be as narrow as is compatible with the proper passage of troops, and is determined by the order of march most convenient for the three arms. Four's for Infantry, two's for Cavalry, and Artillery in subdivisions, would find ample space on a way 9 or 9½ feet in the clear, and this would be also well sufficient for our Indian following.

In regard to the strength of the superstructure, this must be determined by the heaviest carriage that the bridge may be called upon to bear. If we assume a 24-pounder siege gun with carriage and limber to weigh 3 tons, we shall have about 1 ton on each gun wheel, and the breaking weight of the superstructure should be consequently three times, or 3 tons. This would also be ample for the passage of all other heavy carriages and even for laden elephants.

The present system that obtains in all armies of gradually building up this superstructure on the spot by means of Balks and Chesses, and then racking down these latter with cordage, is open to many objections. The Balks in most systems are apt to turn half round or get misplaced and thereby diminish the weight they are able to support. The Chesses and racking down are complained of by every body, as they have to be constantly relaid and renewed during the passage of troops. We lose at least 1½ feet in the breadth of roadway, with the attendant increase of weight in transport as well as that of the small balks, &c., used for racking down. The roadway being built up piecemeal without mutual support, it is necessary to have each Balk, Chess, &c., of a greater scantling and strength than would be necessary if they afforded each other mutual support; and any damage to one of these would render it necessary to relay an entire bay.

Supports, floating.—The row boat is a fundamental necessity for a Military Bridge system, as by its aid alone can we effect the transit of the covering party, and perform the services of all kinds afterwards required, such as laying the bridge itself, performing the police of the river, both up and down-stream, &c. They give us the means of transport across

any breadth and in all depths of water in any velocity of current; they are as stable as Pontoons and ride more easily at anchor. They form therefore the right form of support for Military Bridges wherever floating supports are used; and the troops, more especially the English, would sooner become accustomed to handle them.

In common with all floating supports their use is attended with oscillation and undulation, which wears the bridge and is a source of danger during the passage of troops. In heavy weather this may become so great as to interrupt the traffic altogether. In addition to these defects, which render the employ of fixed instead of floating supports a matter of necessity whenever practicable, it has been brought to notice in the writer's report to the Quarter Master General of the Bombay Army, that there are many cases in which floating supports cannot be used at all.

Wherever these supports *are* employed however, they must be of a stable section and of sufficient buoyancy to bear the heaviest weights that can come on to them. This ultimate buoyancy is found by calculating the greatest number of men that could be jammed into one bay, such as might occur in the event of a hurried retreat of troops, or during an impetuous advance. From 6 to 8 tons ultimate buoyancy would be ample in this connexion. They must also possess sufficient portability to be easily loaded and unloaded on and off the waggons, and carried some distance on mens' shoulders whenever necessary.

They should be capable of being easily and quickly repaired and bailed out, and of having their leaks readily stopped; they should be adapted to carry stores, men, horses, and even light Artillery, and must be constructed of durable materials to stand the hard wear and tear of active service. If made of cloth, canvass, leather, or any thing similar, they would be quickly worn out.

From what has been above stated, it would be clearly inadmissible to have these supports in the form of closed vessels, as two of these have to be rafted together before they can be used at all. By the use of canvass bulwarks and air-tight tubes as sister keelsons, which greatly strengthen the vessel, we secure our row boat from being suddenly swamped, and obtain all the advantages of closed vessels without any of their numerous and fatal disadvantages.

In considering the relative merits of the materials, wood and iron, to which we are reduced by these considerations, we must conclude that for

India corrugated iron boats would be preferable to wooden ones, as in all our campaigns the long land carriage in the sun would split the planks and open the seams of these latter.

Fixed supports.—We now come to the consideration of fixed supports or trestles, which possess numerous advantages as already pointed out over floating supports.

The best form of trestle is that adopted in the Austrian service, and which is in process of introduction into most of the Continental services; a drawing of one of these has been already given.

It is not necessary to persue this subject further, as it will be readily conceded from the remarks that have been made on the nature of Indian rivers, that a system which carries floating supports for Siege Artillery for half the bays in the bridge, and floating supports throughout for Cavalry and Infantry, will accommodate all the rivers met with on active service, as in the case of a river requiring floating supports for Siege Artillery throughout, it would be of such a nature that we should invariably find country craft ready on the spot to answer our ends.

Selection of Bridge sites.—In the selection of Bridge sites we are limited by strategetical reasons to a certain portion of the river's course. This part has to be again subdivided from a tactical point of view, and we find that a re-entering angle is the best position we can select for the passage, as the hostile bank is then swept from our side, which is also usually in this case the commanding ground. If the side from which we embank be wooded and undulating, or possessed of an affluent or island so as to mask our operations and diminish the breadth of the river, our great object of effecting the passage unknown to the enemy would be much facilitated, and we should be saved one of the most difficult and dangerous operations of war, that of forcing the passage of a river in face of an enemy.

The above are the principles which hold good in the selection of Bridge sites, both in advance and retreat, except that in the latter case we should endeavour to get a good start before the enemy, and have a *tête-de-pont* constructed on the hostile bank in which the Artillery remains to the last movement to hold the enemy in check.

The site is connected with the lines of communication in the vicinity in as efficient a manner as our circumstances will permit.

Preparation and details of the passage.—In effecting the actual passage of a river some ruse or stratagem is usually employed by which the

enemy is deceived as to the site selected for crossing, and the train brought up as close to the river's bank as possible at night. After the Artillery have taken up their position to sweep the opposite bank the boats are put into the water and the passage of the covering party effected, during which operation the construction of the bridge may also proceed. Day-break is the proper time for this, and under a proper system of management a few hours should suffice to bridge the largest river.

It is usual in the Austrian and other Continental services to take a rough profile of the river, so as to determine at what places fixed and floating supports are severally required, boats being sent to each place and provided with trestles whenever necessary. A still more compendious method than this will however be indicated when endeavouring to propound a Military Pontoon Train which shall fulfil all necessary conditions.

Carriage of the Train and distribution of the materials on the Waggons.— In a country like India, intersected with nullahs and ravines, and where the few lines of made road are not in those provinces likely to be campaigned over, it is evident that the load of each carriage must be lighter by far than what is considered practicable in Europe, and to this conclusion we are also brought by a consideration of the inferior nature of the draught of the country, that of bullocks. Each carriage therefore should carry but little over a ton in weight.

In regard to the form of the carriage we are limited to 4-wheeled waggons as 2-wheeled carts cannot be used at all across country.* The best form of construction for these is to have the fore wheels capable of locking under the body of the waggons so that it can lock round on its own ground. In order to diminish draught the wheels should be near together, and of as large diameter as is consistent with stability. The gauge cannot be more than 5 feet for the outlying districts, as any one who has had much experience of country roads in India will readily concede. They should be furnished with springs to save the cattle, which are thereby enabled to draw greater loads (say one-third additional) with greater ease to themselves.

In regard to the actual distribution of materials on the Train, the best method of loading is obviously that by which one complete bay is carried

* Why not? Surely two-wheeled carriages are both more manageable and of lighter draught over bad roads. They are used in the Bengal Pontoon Train.—[Ed].

on one waggon, and consequently each can be detached separately. By making each waggon carry its own share of tools, &c., every small detachment is quite independent of the others and capable of availing itself of the local resources and materials on the spot. Any loss or delay of any of the waggons would not affect the remainder of the train in the least.

As against this view it has been argued that a Train should be furnished with special carriages for each special portion of the train—such as store, trestle, balk and other waggons, as thereby the loads are more compact and the line of march of the entire Train shortened by a few feet. There is no doubt of these advantages, but they are trifling when compared with those above enumerated, which greatly increase the value of the Bridge system. Moreover, this system of special waggons complicates much the construction, maintenance and drill of the Train; and has the still more fatal objection, that the loss or delay of any such special waggon, cripples to a certain extent the remainder of the train, and may even do so to the extent of rendering it totally useless.

Construction and details of a perfect Bridge system, which fulfills all the necessary conditions.—We now come to the most important part of our subject, and if the remarks contained in the above discussion be well founded, we find that the following are the chief and indeed essential elements of a bridge system.

1. Easy adaptability to the beds and banks of all sorts of rivers.
2. Stability and firmness as a bridge during the passage of large bodies of Men, Horses and Artillery, &c.
3. Strength and durability as an article of equipment
4. Capability to transit the covering force, and at need the Army itself, when the obstacle is too considerable to be bridged over.
5. Mobility to follow the movements of an Army in the field, and portability for transport by the men at those places where the waggons cannot be taken.

We shall now proceed to bring forward a system fulfilling the above conditions to a perfect extent.

Superstructure.—Instead of the Balks, Chesses, and Racking Down arrangements, which constitute the superstructure of all Military Bridges at present, a little consideration shows us that these should take the form of two Platforms about $4\frac{3}{4}$ feet broad and 20 feet long with a breaking strength of 3 tons. Each of these on the outer sides would be provided

with a light steel chain suspended on uprights sunk in angle iron to keep the carriages on the roadway. In addition to these, which would form the way for the passage of the army and following, there should be a small service platform or way running along side the main road, constructed from the ways by means of which the boats and platforms are loaded on and off the waggons. These ways would be an important improvement on the usual Bridge system; they could be used by the Sappers for all the services of the bridge without interfering with the general traffic, would enable orders to be conveyed to either side of the river, and also a stream of foot soldiers or others in Indian file could be passed at any time from either side to the other, in a direction contrary to the general march.

These Platforms would be strongly keyed on to the capsills or piers; their weight need not exceed 4 cwt. each.

The advantages gained by this system are, greater stability and solidity, which would be more especially useful in perilous circumstances, such as the retreat of an army or an impetuous advance. The weight is reduced at least 40 per cent., and the bearing capacity of the supports is proportionately increased, the points of junction are fewer, and being of iron, would be less likely to wear and get out of order. We have also greater simplicity and quickness in construction.

Floating Supports.—As the row boat has been conclusively shown to be a normal and fundamental necessity for a Military Bridge, it only remains to show how these are attached together to form floating supports for the bridge. By bringing two boats together, stern to stern, they can be formed into one support by means of iron shackles and other fastenings. Two boats thus joined would form a support about 40 feet in length and be much less liable to oscillation than two of the Byrago pontoons. In stability also they would be fully equal to those pontoons, as during the passage of heavy Artillery, the bow and the stern would become gradually immersed and diminish the undulation.

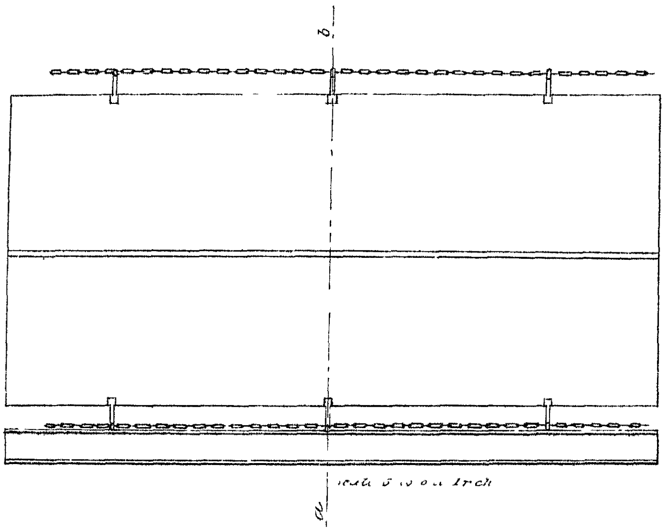
Fixed Supports.—The form already indicated as the Austrian is the best form of trestle that can be adopted, and is the one proposed to be incorporated with the present system. The mortices at the ends of the capsills would be made of boiler plate, and the legs or standards strutted with iron, so as to combine strength with lightness.

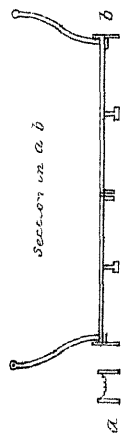
Carriages.—The carriages will be very similar in construction to the

MILITARY BRIDGES.

Proposed Pontoons.

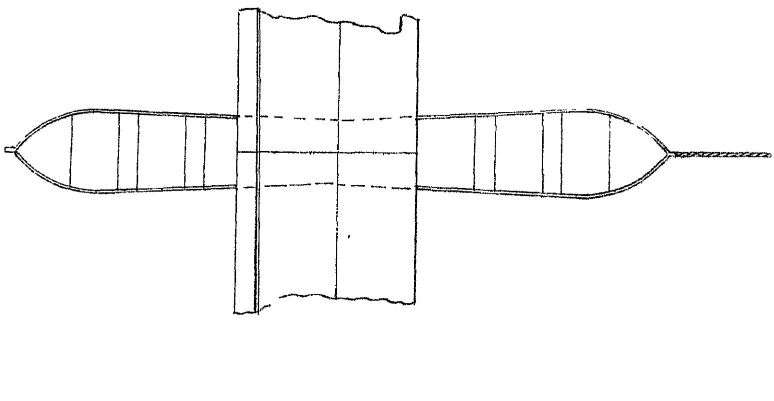
Plan of Platforms and Way



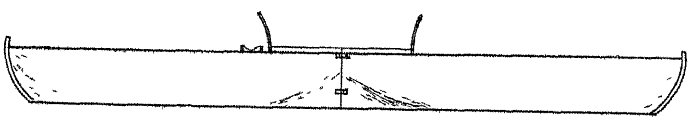


Floating Supports for Siege Artillery.

Plan



Elevation



Scale 12 to one Inch.

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Austrian trestle carriage. They would, however, be furnished with springs and have a larger gauge as well as larger wheels, the fore wheels being 4 feet in diameter and the hind wheels at least 5 feet. The load of each carriage would be as under, carrying each $20\frac{1}{2}$ feet of bridge.

Numbers.	Items.	Weight. Cwt	Qrs.	Lbs.	Remarks.
1	Boat, ...	6	0	0	Of corrugated iron, weight, inclusive of oars, rowlocks, rudder and boat-hook.
2	Platforms, ...	8	0	0	Of angle iron and corrugated iron.
1	Way, ...	1	0	0	Used as construction and service platforms.
1	Capsill, ...	1	1	0	These items form one complete trestle.
1	Standard, 8 feet, ...	0	1	2	
1	" 12 feet, ...	0	1	22	
2	" 16 "	1	0	0	
1	" 20 "	0	2	7	
2	Wedges, ...	0	2	0	
2	Shoes, ...	0	1	12	
2	Suspension chains, ...	0	1	6	
1	Screw-jack, ...	0	1	8	
1	Anchor and cable, ...	1	2	0	
1	Mallet, ...	0	0	4	
1	Canvass bulwark and sticks,	0	0	8	
1	Scoop, ...	0	0	2	
		21	2	15	
	Proportion of artificers' tools, say, ...	1	1	13	
21	Total, ...	23	0	0	One ton three hundred weight.

On the forge waggon we should carry two platforms, one way, and the two landsills, on which the shore ends of the bridge rest, in addition to the necessary tools, &c.

Our length of Train would be determined by the medium size of rivers of the 2nd class, which would be for India about 100 yards long. Fifteen waggons with one forge waggon would give us 328 feet of bridge or $109\frac{1}{3}$ yards, and be well capable of covering 100 yards of waterway.

We shall have our waggons much more lightly loaded and more mobile than the Austrian, which latter we should find very difficult to move across country with the present bullock draught. To compare these two systems together as far as regards the weight per foot run, we have the following comparative table:—

	Weight per foot run.			Remarks.
	Byrago.	Proposed.	Per centage of proposed system and Byrago's.	
Siege Artillery, ...	179	118	0·61	
Cavalry in Indian file and Infantry in file, ...	96	59	0·61	
Infantry in Indian file, ...	77	39*	0·51	* Using some supports of circumstance.

In the actual laying of this bridge the simplicity of the details would afford us great facilities for the construction by the method of booming out, as practised in the English service wherever the stream was sufficiently sluggish to allow of that operation. But when the stream was too rapid to permit of this system, our row boats would enable us to lay the bridge with ease and rapidity. Each boat as soon as slid into the water by means of the ways, (which would also be used in unloading the platforms, &c.,) would take on board a complete trestle and way; in fact the entire load of one waggon, except the platforms and artificers' tools. The first boat would take over a wire rope marked at intervals of $20\frac{1}{2}$ feet (being the length of one bay) being assisted by one or more boats, according to the breadth of the stream, and the remainder would row up to their places at once and anchor there. Those boats that found the water sufficiently shallow for trestles, would fix them immediately, directly opposite the mark on the rope, and the light warps would then be thrown across from one pier to the other, and a communication for foot soldiers would be at once estab-

lished between bank and bank. The boats that had fixed trestles would then proceed to those places where floating supports were required, and attach themselves to the boats already there. The platforms would be then brought on by hand from the shore by means of these warps and keyed on to the piers.

This system is evidently capable of performing all that is claimed for the Byrago Pontoon Train; with the exception that these new boats cannot be joined end for end like the Austrian; but as they would be far superior as rafts and flying bridges, we need attach but little importance to this.

To recapitulate therefore, and in conclusion, we may justly claim the following most important advantages over the Austrian system.

Greater mobility and capability of division, which would be more especially beneficial in a country like India abounding in nullahs on the line of march, greater stability and solidity and lateral stiffness, which would be of the highest value in perilous circumstances, and improved facility and quickness in passing Armies in the field over considerable obstacles. As all these have been attained with a great decrease in weight, being indeed a reduction of at least 40 per cent. on the Austrian system, it is trusted that a sufficient case has been made out to induce discussion by professional men.

ALEX. COWPER, LIEUT.-COL., R.E.

MHOW,
1st *January*, 1865.

NOTE BY EDITOR.

The chief difference between the form of pontoon or boat advocated by Colonel Cowper and the Byrago pattern is, that he employs two separate boats fastened together, instead of two half boats. The Byrago bateaux can be used with or without the middle piece, and in the former case do not differ essentially from Pasley's Pontoons or demi-canoes, as now used by the Sappers in the Bengal Army, which are thus described by Sir H. Douglas (Military Bridges):—

"Sir Charles Pasley's pontoons, or canoes, are, each in its whole length, 22 feet long, 2 feet 8 inches broad in its greatest width, and 2 feet 8 inches deep. Except the deck, the vessel is formed of sheet copper, covering a wooden frame, and the deck is

of wood. Each is formed in two equal portions and each demi-pontoon is divided by a transverse partition, in order to prevent the water from filling the pontoon, should a hole be made in it by accident; and a pump is provided for the purpose of drawing the water off. Light carts, with two wheels, each drawn by two horses, will convey two demi-pontoons with their stores; thus two carts will convey the two pontoons, with all the materials necessary for forming a raft, which, when put together, will constitute a portion of the bridge.

"When the banks are favorable for launching the pontoons, any number of rafts, with the complement of hands, can be put together and launched in a quarter of an hour; in another quarter of an hour the bridge can be formed The bridge may be dismantled in 8 minutes, and in a quarter of an hour afterwards the rafts may be run ashore, taken to pieces, and the pontoons with their stores packed on the carriages"

Similar boats or bateaux, except that they are not divided in the middle, and which will be described further on, are used in the French service; and as no other Army except our own uses the cylindrical pontoon, the weight of authority and custom is certainly against it. For Civil Bridges, however, it is certainly preferable to the boat (*vide* Professional Papers, Vol. I., p. 209), but the conditions are very different from those now under consideration.

That the superstructure proposed by Colonel Cowper would be an improvement on that now in use when once it was laid, may I think be admitted. It would not of course be so portable or so handy.

With regard to Trestles, it is impossible I think to doubt their utility as adjuncts to the floating supports, in many cases of Indian Rivers, especially where the water is too shallow to admit of the boats floating properly. But the Byrago Trestle has been tried by the United States Engineers in the present American War, and appears to have been condemned, while the French system is strongly recommended as the best yet devised. As this experiment is the latest that has been made in actual war on a large scale, and the United States' Engineers are well known to be Officers of great ability, I give the following extracts from the "Report of Brigadier General Barnard, Chief Engineer with the Army of the Potomac, published at New York in 1863," which will be found full of interest (all the italics are in the original):—

"The engineer equipage consisted of about 160 bateaux or wooden pontoons of the French model, with the necessary balks, chess, anchors, cordage, &c. There were also a certain number (of which I do not now find any exact statement) of Birago trestles, and Russian canvas boats.

"As originally got up, this bridge equipage was organized in *trains*, of which there were six regular trains, consisting each of thirty-four French pontoons and eight Birago

trestles, calculated to make a bridge of about 250 yards length; and an advanced guard train composed of Birago trestles and Russian canvas boats. The waggons for but four of the regular trains and for the advanced guard were provided.

"A word is proper here concerning the Chickahominy, which, at the season we struck it, was one of the most formidable obstacles that could be opposed to the advance of an army; an obstacle to which an ordinary *river*, though it be of considerable magnitude, is comparatively slight. The Chickahominy, considered as a military obstacle, consists of a stream of no great volume, a swamp, and a bottom-land.

"The stream flows through a belt of heavily timbered swamp, which averages three to four hundred yards wide. A few hundred yards below New Bridge is a short length of the stream *not* margined by swamp timber; but everywhere else between New and Bottom's Bridges, the belt of swamp timber is continuous and wide

"Through this belt of swamp the streams flows, sometimes in a single channel, more frequently divided into several; and, when but a foot or two above its summer level, overspreads the whole swamp.

"The *bottom-lands*, between the swamp and high-lands, are little elevated at their margins above the swamp, so that a few feet rise of the stream overflows large areas of them. They rise very gently towards the foot of the highland slopes. These bottom-lands are generally cultivated, intersected by deep ditches, and their lower portions are, in wet weather, even when not overflowed, spongy, and impracticable for cavalry and artillery. The total width of bottom-land varies from three-fourths of a mile to a mile and one-fourth.

"The pontoon equipage which accompanied the army was got up (as already mentioned) by Lieut.-Col. Alexander, assisted by Capt. J. C. Duane. The former had acquired an enviable reputation as the builder of the Minot's Lodge Light-House; possessed great practical ingenuity, and had had the means of knowing the best results arrived at in other services in this branch of military art.

"Captain Duane possessed a more extensive and thorough practical and experimental knowledge of military bridges than any other man in this country.

"They gave, after full consideration of the subject, their preference to the French system. Even had they adopted this system blindly, *because* it was French, they would not have been without solid reasons, for the French have studied and *experimented* upon the best systems known to the world. Whatever may be said about the difference in the character of the country, roads, etc, the thing *to be done* here and in Europe (now that our armies have assumed European magnitude) is essentially *the same.*

"But these officers had before them the best *modern inventions* of Europe and America. The India-rubber pontoon they knew *thoroughly*; corrugated iron bodies, and countless other "inventions" of American genius, were before them, and the former experimented upon.

"My own prepossessions had been in favor of the Birago system of sectional pontoons, and "Birago" (so called) trestles.

"The experience we had, proved the wisdom which adopted the system in question. Not to advance, by any means, that nothing better can be found (the substitution of iron for wood was one of the probable improvements well understood by the officers named, but not, *at the time,* adopted, for substantial reasons), it is enough to say that the French pontoon was found to be most excellent, useful, and reliable for *all* mili-

tary purposes. They were used by the Quarter Master's Department in discharging transports; were precisely what was needed for the disembarkation of General Franklin's division; constituted a portion of the numerous bridges built over Wormley Creek during the seige of Yorktown, and were of the highest use on the Chickahominy, while over the lower Chickahominy, some 75,000 men, some 300 pieces of artillery, and the immense baggage-trains of the army, passed over a bridge of the extraordinary length of nearly 650 yards; a feat scarcely surpassed in military history.

"The Birago trestles, of which I had formed so high an opinion, proved itself dangerous and unreliable; useful for an advanced guard or detachment, unfit, in general, for a military bridge. Of the American India-rubber and the Russian canvas pontoon we had no fair experiment. They may both be useful; but again, I think, not reliable for a "military bridge," considered in all its aspects and uses.

"The weight of the French pontoons is objected to, but a *certain flotation power is required* which it is not easy to get, nor are the ways unobjectionable which seek to get it with less weight; and the vehicle which carries it is not heavier loaded than other vehicles of an army train. *Less length* would certainly make it more manageable on our narrow roads, while, for advanced guards and dashing minor enterprises, greater lightness is requisite. Perhaps an iron sectional pontoon may be contrived which will meet these requirements, but prudence demands that the safety of an army shall not be jeopardized by giving it a bridge which experiment has not fully tested. American genius is fertile in this as in all other expedients, but no genius can provide for an object which is not understood.

"The numerous proposers of "flying" bridges forget that, if a military bridge is intended to be *carried with* an army, it is also intended to *carry* an army, its columns of men, its cavalry, its countless heavy waggons, and its ponderous artillery. It must carry all these, and it must do it with certainty and safety, even though a demoralized corps should rush upon it in throngs.

"No make-shift expedient, no "ingenious" inventions, not tested by severe experiment, nor light affair, of which the chief merit alledged is that it is light, will be likely to do what is required, and what the French pontoon has so often done."

The following description of the French Pontoon above alluded to is from an instructive Paper by Lieut.-Col. Lovell, C.B., R.E, in Vol. XII., of the R. E. Professional Papers:—

"The new pattern French pontoon or bateau (introduced in 1853) is 31 feet long, the bottom and sides being of fir planks about 1 inch thick, nailed to a framework of wooden ribs 3 inches by $2\frac{1}{4}$ inches. The bateaux are quite open and have a flare bow and stern, the latter being rather shorter than the former. As ordinarily arranged in bridges, these bateaux are placed at intervals of 19 feet 8 inches, when the bridge has a power of 644 lbs per lineal foot, and is quite equal to any ordinary load. When required for extraordinary loads, the necessary power is obtained by diminishing the intervals between the pontoons. For transport, two pontoons and the material for the superstructure of two bays of the roadway are subdivided between three waggons, each drawn by six horses, and weighing about 4,670 lbs. (778 lbs. per horse). The anchors, of which one is allowed to each of these bateaux, weigh about 145 lbs. Finding that these bateaux, in consequence of their great length, are very unwieldly

when loaded on their waggons, the French pontooners have lately proposed and made an equipment of demi-bateaux, each of which is just half the size of those which they at present employ, and with the buoyancy of which they express themselves as being perfectly satisfied."

The following table extracted from Col. Lovell's paper shows the comparative size, weight, and flotative power of the pontoons above described, to which I have added a column to include Colonel Cowper's, as far as I could determine the details:—

	French, present general pattern, open wooden beateau	Austrian Byrago present pattern, iron; open bateau two bows and one middle piece	English, Pasley, copper, demi-canoes, with wood deck.	English Blanshard, cylinder, tin, hemispherical ends, open order.	Colonel Cowper's pattern.
Total length of pontoon over all, ft.,	30 93	39·41	25 0	22·5	40·0
Width of do, greatest section, ft., ..	5 06	6 22	2·75	2 66	5·0
Depth of do., midships, ft., ...	2 58	2·59	2·58	Diam.	3·0
Displacement do., c. ft., ...	321 04	530·16	140·5	108 56	170·0
Ditto, do., lbs., ...	20,065	33,135	8,781	6,785	16,625
Weight of pontoon, lbs., ...	1,323	2,532	778	482	672
Do. of one bay of superstructure, lbs.,	1,830	1,969	1,325	1,120	896
Power of support, total lbs., ..	16,912	28,634	6,678	5,185	9,057
Do. do. for load; three-fourths for open pontoon, nine-tenths for close do., lbs., ...	12,684	21,476	6,010	4,667	6,793
Interval in Bridge, ft., ...	19·69	21·67	12 5	12 5	20 0
Power per lineal foot of roadway, lbs, ...	644	991	481	373	340
Greatest possible load at 110 lbs. per foot (superficial), lbs., ...	1,082	1,026	1,100	1,100	1,045
Greatest ordinary load, 560 lbs. per foot (lineal), lbs., ...	560	560	560	560	560
Width of roadway, ft., ...	9·84	9·33	10·0	10·0	9·5
Weight of Pontoon per cubic foot of displacement, ...	4·12	5·49	5·83	5·43	3·95
Area of greatest immersed transverse section of Pontoons per lineal foot of Bridge, when arranged to support, on each foot of a roadway 10 feet wide, a load of 1,100 lbs., ...	·898	·615	·956	1·026	
Do., do. do. do. 560 lbs., ...	·472	·322	·513	·541	

Although I have inserted the above table, it does not appear to give any satisfactory means of comparing the different patterns according to the work which each can perform. Some of the dimensions and weights too, differ from those in the text above.

No. LVII.

PURTAPORE STONE QUARRIES.

By T. E. Owen, Esquire, *Assistant Engineer.*

A large amount of stone being required for the new Public Offices in Allahabad, it was considered advisable to open a Quarry, as the only means of breaking the monopoly hitherto enjoyed by the leading Mahajuns, who by making advances to zemindars and others, where stone was procurable, kept the supply in their own hands and naturally charged enormous prices.

The place fixed upon was at Purtapore, a village on the banks of the Jumna, thirty miles from Allahabad, where the valley of the river towards the south is narrowed by a range of low hills; the underlying strata of which, here and there, crop out into the bed of the river.

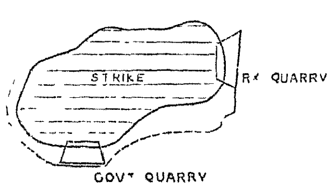
These hills form the outer scarp of the Vhyndian system, towards the north, and apparently belong to the lowest group of that great system, viz., the Kymore group; they are low irregular hills, partially covered with the scantiest jungle, and strewn with large boulders of white crystalline sandstone, generally capped with massive beds of the same material.

The quarries at Purtapore are worked in a small hill, about 160 feet high, slightly isolated from the range. This offers peculiar facilities for quarrying as it can be worked on any side, and its underlying strata, from which alone good stone is procurable, seem to be considerably raised above the level of the same beds, visible (and in some places worked) in the face of the scarp of the range. The strata worked is a fine grained compact sandstone, of a light reddish color; it is extremely homogenous, moderately

hard and suitable for every kind of work, from the large blocks of the Jumna bridge piers, to the elaborate carvings of a church.

When first quarried it is softer than it afterwards becomes when exposed to the air, owing probably to the deposition of the natural cements before held in solution. The hill is capped to a depth of from 40 to 50 feet, with massive beds of white crystalline rock, of flinty hardness, with a conchoidal fracture; its strike is about two points to the north of west: under this for a depth of about 40 feet, beds of soft friable sandstone are met with, crushed and distorted to a great degree; then from 4 to 6 feet of shales immediately above the workable stone. This stone lies in beds of from 6 inches to 8 feet in thickness; its strike is nearly due west; it has no apparent dip, and is extremely fissile in some beds, but has no cleavage, properly so called; the lower the beds, the further they crop out from the hill, and the more compact and homogeneous the stone, generally speaking.

The selection of a site is attended with great uncertainty, as the stone crops out from the hill very irregularly, but as a rule further in the direction of its strike. The sketch shows roughly the outline of the hill; with the underlying stone strata where known; and dotted, where supposed to lie; boring might often be employed with great advantage, where it is desirable to know how far the stone beds crop out from the hill, but a boring apparatus of great strength would be necessary to penetrate the hard boulders.



The Government quarry was commenced in June 1863, on the north side of the hill, where it was steeply scarped towards the top, which appeared to give a good face to work up to. For the first month, progress was merely nominal. Workmen were not easily procured for this kind of work; there were preliminary operations to be got through, such as building houses for an Assistant Engineer and Overseer, sheds for workmen, stores, bullocks, &c., for which all materials, except rubble, had to be procured from Allahabad. Cholera broke out at this time badly, the European Overseer being one of the first victims, so that it was not till October that an adit of 20 feet wide was cut into the face of the hill down to the stone beds; a considerable area to one side was also partially uncovered, unfortu-

nately as it turned out, as the stone beds appearing to thin out in this direction, the present quarry had to be opened out on the other side. It is difficult to fancy any more tedious work than the excavation of this adit. First the large surface boulders had to be removed; then for a depth varying from 6 to 12 feet the work consisted in blasting and removing boulders and irregular beds of rock, imbedded and wedged in by small stones and a tenacious clay, so that stone-cutters had to be employed for blasting and cutting up the beds of the rock, bundanies for removing these and all boulders and stone above a certain size, bildars and coolies for excavating and removing the soil and rubbish. None of these would work without the others, and *having* to work together, but a few of each could be employed in the limited space; the rains too continually stopped the blasting, and consequently the whole work.

The adit having been opened down to the stone beds to an average depth of 40 feet, the most favorable direction for continuing the work was seen, and the clearing of 20,000 square feet of stone beds being sanctioned, a space 170 feet at top, 230 at bottom, was marked off; of this the greater part has been cleared to workable stone beds, and the remainder will be finished during October 1864.

The length of the quarry runs in the direction of the strike, and the stone beds are continuous the whole length, in almost perfectly horizontal beds, forming a most valuable quarry, from which stone of all dimensions can be rapidly and cheaply quarried now that the opening is completed; and the cost of such, being no longer indefinite, there can be no doubt of its great advantage and success in a pecuniary point of view. Supposing the quarry to be worked to a depth of 20 feet (the railway quarry has been worked to a greater depth), at least $2\frac{1}{2}$ lakhs of ashlar and one lakh of rubble can be procured; the cost of opening the quarry will add less than 2 annas per foot on to this amount of ashlar, and the cost at per cubic foot will be—

	R.	A.	P.
Opening quarry, ...	0	2	0
Quarrying (with contingencies,)	0	3	0
Carriage to boat (including cost of tramway,) . .	0	2	0
" by boat, ...	0	1	6
" to site of building, ...	0	1	6
Total, .	0	10	0

10 annas per cubic foot for ashlar of all sizes delivered at site; whereas

the prices rating in Allahabad at the time the quarry commenced ranged from Rs. 1-2 to Rs. 2-4, per cubic foot, according to size.

From various causes, but chiefly from the delay in the sanction of the new Public Offices at Allahabad, the work was not pushed on so fast as it might have been until the month of April 1864, when every exertion was made and as many men placed on the work as could possibly work together; from twenty to thirty-five blasts were fired every day in this month, working on an area of 12,000 square feet; 80,000 cubic feet were excavated and removed, which gives in round numbers 6½ feet as the average depth of excavation per month for this description of work; of this at least 50,000 cubic feet were broken or loosened by blasts. The area of the quarry, within certain limits, signifies little, the number of workmen who can be employed being proportional to the space. This work has for sometime been done by contract at Rs. 16 per 1,000 cubic feet down to good stone beds, being Rs. 12 for excavation, blasting, and removal of rubbish, and Rs. 4 for the removal of the larger boulders by bundanies. The lead for spoil being on an average 200 feet, powder and tools being supplied by Government, the contractor also received Rs. 1-8 per 1,000 cubic feet for all rubble procured during the excavation. Up to the first of October 1864, 650,000 cubic feet have been excavated.

Up to the above date 2,400 lbs. of blasting powder have been expended, which gives 3·7 lbs. per 1,000 feet of excavation. Three sizes of jumpers were used—for hard boulders, 1½-inch; for loose sand-stone and shales, 2¾-inch; for shallow beds of the same, 4½-inch. They were 12 and 8 feet long, tipped at both ends; the 1½-inch taking ¼ seer of steel for both ends; the 2¾-inch taking ¾ seer; the 4½-inch taking 2¼ seers. In hard stone the 1½-inch, using both ends, would jump 3½ feet without being sharpened. The sandstones and shales vary so much that it is difficult to give a like average for the 2¾-inch jumpers. In hard stone, with 1½-inch jumpers, two men *could* jump a hole 3 feet in a day, but the average was not so good; with a 2½-inch jumper, they could not do more than 1 foot 8 inches.

In moderately hard shale, two men could jump two holes 2¾ inches, 3½ feet deep in the day, but not so much with deeper holes; in the friable sandstone, two men could jump 2 holes 2¾ inches from 8 to 12 feet deep.

At first, stone-cutters were employed for jumping, but afterwards beldars were taught and paid at the rate of 2½ annas per day. The charges for

blasting were calculated on the "the cubes of the lines of least resistance," taking a 4 ounce charge for 2 feet as the standard; thus a 3 feet line of least resistance would require $3^3 : 2^3 :: x : 4$ ounces $\therefore x = 13\frac{1}{2}$ ounces. This was found to answer well for stone; and for shale $\frac{2}{3}$ of this was ample; but the loose sandstone took considerably more, though soft; the sand being cemented with a soft argillaceous cement, it was compressible and withstood the shock better.

The tamping was of clay, moderately dried in small rolls in the workshop. Cartridge paper soaked in a solution of 1 ounce of saltpetre and 4 ounces of water, was used for igniting the charges. Rammers with copper ends, copper needles, and long iron scoops were all made on the works.

No serious accident has occurred in the quarry or in blasting twice men have been slightly burnt from carelessnesss in lighting the touch paper.

The tools used for quarrying are very simple; large hammers and wedges, which are supplied by Government, and small hammers and chisels, which the workmen themselves procure.

The large hammers and wedges are best made from the raw country iron; those made of English iron (as procurable in the Indian market) are very inferior and break or crack after a few days work; country iron being extremely tough scarcely ever breaks, and the hammers and wedges when gradually flattened by use can easily be made up again. The iron used here comes from Rewah on pack-buffaloes, in pieces of from 10 seers to 1 maund in the rough state. From a piece weighing $7\frac{1}{2}$ seers, 6 seers of iron was worked into a wedge, but the average is not so good, being about 60 to 70 per cent. The price of this delivered at the quarries is from Rs. 4-8 to 5 per maund.

The working of this from its rough state, of course involves a great deal of manual labor, and costs from Rs. 10 to 18 per maund, but the product is excellent, which may be attributed to the original quality of the iron, to the hand forging, or charcoal fuel, but probably to all three combined.

The stone lies in beds, through the breadth of which it is first necessary to chisel a trench, in order that blocks may be split off; a trench 28 feet long in a bed 2 feet 4 inches deep, cost Rs. 58. This trench was 1 foot 6 inches wide at top, 8 inches at bottom, giving a cubical content of 70 feet; this gives $13\frac{1}{4}$ annas as the cost of chiseling out per cubic foot, paying the men at the rate of 6 annas per day, but I think it *might* have been done cheaper than this.

The method of working the stone is this; the dimensions having been marked off, holes are chiseled along these about 3 inches apart, from 3 to 6 inches deep, from 4 to 6 inches long and $2\frac{1}{2}$ inches wide, into which wedges are put, and struck from end to end of the line with heavy hammers, until the stone is split. This is precisely the same method as that in use in England, and was probably known in India before England existed as a nation; old Bhur forts near shewing marks of smaller wedge holes.

The rates I am now paying for quarrying are—

	R.	A.	P.
For ashlar, 1 to 20 cubic feet, per foot,	0	2	0
„ 20 to 40 „ „	0	2	6
„ flags, two inches thick, „	0	3	0
Rough dressing the ashlar, „	0	1	0
For large rubble, per 100 cubic feet,	3	14	0
„ small „ „	1	8	0

The ashlar is rough dressed before it is taken out of the quarry; this has been found to save $\frac{2}{5}$ths of the carriage.

The Establishment at present consists of—One Assistant Engineer—an English writer—Two Moonshees—One Jemadar—A police guard of one head and four men. Head stone-cutters and head bundanies receive from Rs. 14 to 16 per mensem, stone-cutters from annas 4 to 6, bundanies annas $4\frac{1}{2}$ per day.

A double line of tramway leads from the quarry to the river; two derricks will soon be erected in front of the quarry, as soon as these are completed, all ashlar will be hauled out of the quarry on to the trucks, (which will run along the face of the quarry) at once, and propelled by coolies to the river bank. In the dry season when the river falls 40 feet below the level of the end of the tramway, it is proposed to lower the laden trucks (which at the same time pull up the empty ones) by a chain passing round a drum, with a brake, on a tramway running on a rubble embankment pier, 450 feet long, with a slope of 9 in 100, and a 200 feet level at the end. The total cost of the tramway 2,500 feet long, with thirty trucks, including five lakhs of earthwork, will be about Rs. 14,000. The probable rates for leading and loading, with the tramway will be

Ashlar, 1 to 20, at 8 Rs. per 100 cubic feet.
„ 20 to 40 at 12, „ „
Large rubble and flags, at 4 Rs. per 100 cubic feet.
Small „ „ 1 „ „

The East Indian Railway Company work a quarry 380 feet long by

about 120 feet broad, from which a great portion of the large ashlar for the Jumna Bridge has been procured. They have a single line of tramway to the river at a very low level; this saves the necessity for steep gradients, but is useless during the rains and for a month after, being covered for several hundred feet with a deposit of silt from 4 to 10 feet deep. When the work was first commenced a masonry pier was built into the river, but was unfortunately swept away during the ensuing rains; a temporary earthen pier is now made every year to carry on the work during the dry season. This is a very fine quarry, and has beds 7 feet thick in many parts.

Tramway.—The tramway from the quarries to the high bank is 2,400 feet long, with a descending gradient from the quarry, in some places ·5 in a 100, in others 2 in 100; it has three sharp curves running into each other, whose radii are respectively 425, 300 and 225 feet. The loaded trucks run with considerable velocity down the 2 in 100 gradient, but are sufficiently checked and easily brought up, without a brake, on the gradient of ·5 in 100 of the end. According to the formulæ for raising the outer end rail in curves, *i. e.*, $\frac{R - r}{R \times r} \times W\,8^2 \times {\cdot}782 =$ super-elevation in inches.

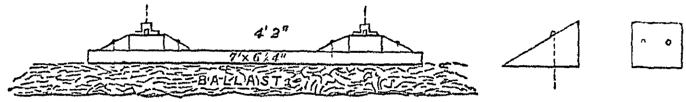
Where R = least radius (in this case 1,200 feet).
,, r = radius of curve.
W = width between rails.

and taking 8 miles per hour as the greatest velocity; the outer rail in the sharpest curve, *i. e.*, 225 feet, would only require to be raised nearly ½ inch.

But, practically, this was not found enough; probably the smaller flanged wheels and the less perfect laying down of a tramway require a modified formula. A super-elevation of 2 inches in the outer rail was found necessary. The formation level was made 20 feet wide to allow for a double line of tramway 8 feet from centre to centre, and a pathway along one side.

The transverse sleepers were laid upon a 6-inch bed of ballast about 9 feet apart, they were 7′ × 6″ × 4″; over these the longitudinal sleepers were laid, their joints meeting over the transverse sleepers, and fixed in position by chucks of wood on each side, secured on the outside by two

6-inch nails, on the inside by one do. The chucks were easily and cheaply made out of the ends of the sleepers, which had to be cut to uniform lengths.



The rail is a small bridge rail, weighing 14 lbs. to the yard; generally in 10 feet lengths, fastened by 4-inch nails to the sleepers; in each length there are 10 nails. No drill holes are required for these in the timber, but they penetrate much better if wetted before being driven in; in very dry weather they are apt to jump back when struck without this precaution.

The line being ballasted up to the top of the sleepers, it was found that a 2-inch layer of fine gravel or budgeree over this was of great service in binding down and so consolidating the ballast, as to fix the longitudinal sleepers immoveably and prevent any vibration.

The trucks are of two sizes, the larger 8 × 8 feet for the carriage of rubble, the smaller 7 × 4 feet for ashlar; they run up on 2 feet 3 inches wheels with $2\frac{1}{2}''$ axles, and are made of strong framed saul, strengthened by bolts and ties; the 8 × 8 feet trucks carry as an ordinary load 150 cubic feet of rubble, weighing about $1\frac{1}{4}$ cwt. per cubic foot = 188 cwts. = $9\frac{1}{2}$ tons, nearly; five men are required to propel these loaded trucks with a descending gradient, and three men to push back the empty ones with an ascending gradient.

The ashlar is now lifted by an ordinary derrick out of the quarry, at once on to the trucks; no blocks over 25 cubic feet have yet been lifted.

The rates for earthwork (cutting) were, down to 6 feet, Rs. 3; from 6 to 12, Rs. 3-8; 12 to 16, Rs. 4; 16 to 20, Rs. 4-8; with a lead of 200 feet from the top of the slope.

For turfing slopes, 2 annas per 100 square feet.

For dressing „ 1 „ „

For breaking ballast to $2\frac{1}{2}''$ gauge, 12 annas per 100 cubic feet.

For spreading ballast, with an average lead of 1,000 feet, 8 annas per 100 cubic feet.

The woodwork was bought at 4 annas per cubic foot; in every 100 running feet of single line there are 11 transverse sleepers = $11 \times 7' \times 6'' \times 4''$ = 13 cubic feet, and 200 running feet of longitudinal sleep-

ers, $6'' \times 5'' = 96$ cubic feet; total 109 cubic feet. Add $\frac{1}{10}$th for wastage in cutting, which gives 120 cubic feet per 100 running feet of tramway. The cost including carriage, would be nearly 5 annas per cubic foot.

Therefore the cost per 100 feet of line

would be— $\frac{120 \times 5}{16}$	=	37 8 0	37 8 0
The cost of laying was—			
Cutting 11 transverse sleepers, to 7 ft. length,	=	0 8 0	
" 22 longitudinal sleepers, to uniform lengths, ...	=	1 0 0	
Making 44 chucks,...	=	0 12 0	
Drilling 132 holes in ditto, ...	=	0 6 0	
Laying transverse and longitudinal sleepers in position, ...	=	1 6 0	
Hammering 132 nails in sleepers, ...	=	0 4 0	
			4 4 0
Total cost of woodwork per 100 r. ft. of single line,			41 12 0

N.B.—In curves (sharp) it costs $\frac{1}{8}$th more to cut the longitudinal sleepers.

The cost of laying the rails was very slight, except in curves where the rails had to be bent; this cost about Rs. 2 per 100 running feet of single line; it was done by beating the rails till nearly red hot in ooplah, then striking them with a mallet on a gauge bent to the required curve.

The rate for conveying rubble by the tramway, *i. e.*, loading, leading and unloading trucks, and stacking at ghât, is Rs. 1; for large rubble, Rs. 4.

The leading and loading of ashlar will probably be reduced next month to $1\frac{1}{2}$ annas per cubic foot, as the tramway is now in good working order.

The tramway itself requires 1 smith and 1 beldar to keep it in order.

T. E. Owen.

No. LVIII.

RATES OF WORK IN BENGAL.

[The following Circular was addressed by the Editor in July last, to the Controllers of P. W. Accounts in the several Provinces—their replies as received will be published.]

To the Controller and Examiner of Accounts, Public Works Department, ———— Circle.

Roorkee, 1st July 1864.

DEAR SIR—It has been suggested to me that it would be of essential service to Officers of the Department, generally, to collect and publish in the Engineering Papers which are issued quarterly from this press, the various rates of work obtaining in different parts of the country *at the same time;* and to enable me to do this I beg to solicit your aid.

I enclose a printed list containing most of the rates in ordinary use, with spaces for additions if necessary, and I would request the favor of your filling up the columns and returning the list to me at your early convenience.

I have, &c.,

J. G. M.

[In the following Tabular Statement received from Bengal, I have omitted those items which were returned blank.]

TABLE OF RATES ARTMENT, IN OR ABOUT THE MONTH OF MAY, 1864.

Details		Burrakur.	Burdwan.	Midnapore	Balasore.	Cuttack.	REMARKS.
RATES OF LABOR.							
Stone Masons							
Mistrie Mason,	)	11 4 0	...	...	...	9 8 0	
Skilled workman, ...		...	...	...	...	0 4 0	
Ordinary do, .		...	...	...	...	..	
Bricklayers							
Mistrie Bricklayer, ...		9 6 0	...	5 10 0	...	...	
Skilled workman, ..		...	..	...	...	...	
Ordinary do. ...		...	0 3 0	0 2 0	...	...	
Carpenters.							
Mistrie Carpenter, ...	0	9 6 0	...	7 8 0	...	7 8 0	
Skilled workman, ...		...	0 5 0	0 3 0	...	0 3 6	
Ordinary do., ...		..	0 5 0	...	...	0 2 9	
Smiths.							
Mistrie Smith, ...	0	20 0 0	...	...	...	...	
Skilled workman, ...		...	...	...	...	...	
Ordinary do, ...		...	...	...	...	...	
Painter,		...	0 3 0	0 4 6	...	...	
Grammie,	0	0 5 0	0 3 0	...	...	...	
Bheestie,	0	...	..	...	...	...	
Laborers,							
Beldar, ...	6	...	0 1 6	...	...	..	
Mate coolie, ...	0	0 2 6	4 0*0	0 2 0	0 2 0	0 2 6	
Coolie, ...	0	0 1 3	0 2 0	0 1 6	0 1 6	0 2 0	
RATES OF MATERIALS.							
Stone, best quality, hammer dr at the quarry, ...		1 1 0	...	...	...	...	
Bricks (best), 12″ × 6″ × 3″ at	0	6 0 0	5 6 0	...	...	...	
Ditto (seconds), ditto,		...	5 6 0	...	2 8 0	3 8 0	
Ditto (best), 9″ × 4½″ × 2½″,		...	...	...	2 8 0	3 8 0	
Tiles, common, native, at kiln,		...	...	...	...	...	
Tiles, Goodwyn's, large, at kil		...	...	..	...	...	
Flooring tiles, 12″ square 1½″ at kiln, ...		...	1 2 0	...	..	...	
Lime, best kunkur, at kiln,	0	...	28 4 0	...	18 0 0	...	
„ stone, do.	0	...	...	...	...	...	
Chunam, for polished surfac kiln, ...		...	...	...	...	...	

	ONS.								
	Dinapore.	Shergotty.	Hazareebaugh.	Burrakur.	Burdwan.	Midnapore.	Balasore.	Cuttack.	REMARKS.
RATE									
Soork									
Sand, car	0 9 0	5 0 0	4 0 0	..	6 2 9	..	6 4 0	8 0 0	
Kunk	..	..	..	..	..	..	..	..	
Broke car	7 4 0	..	..	..	..	..	..	..	
	..	..	..	..	..	..	..	3 1 0	
Saul, carı									
Teak,	..	1 8 0	..	1 8 0	..	..	0 12 0	0 8 0	
	..	..	..	2 12 0	..	..	..	..	
2-Bull	..	..	..	..	..	..	..	..	
Collect clud mile									
Consol	..	3 12 0	..	..	..	..	3 8 0	3 2 0	
cubi *a.* K	0 0	4 8 0	..	..	..	..	..	..	
Earthw or sa up t bank									
Ditto, k able the ı in ba	0 0	2 8 0	..	..	2 8 0	..	2 4 0	2 2 0	
	..	..	..	..	..	..	..	..	
Excava where quired									
Concret	..	..	..	..	..	..	..	..	
	..	..	..	..	..	..	8 0 0	5 8 0	

Details.	Burrakur.	Burdwan.	Midnapore	Balasore.	Cuttack	REMARKS.
Stone-work.						
(All set in best mortar.)						
Rubble, ...	..	..	..	..	..	
Flagged flooring or roofing,	..	..	..	..	..	
Brickwork.						
First class Brickwork, with ı or dressed face (on one side set in best mortar with clo 0 ting joints up to 5 feet high	10 0 0	..	..	17 0 0	15 0 0	
Second class brickwork in walls best bricks, (not dressed) best mortar, ditto, ..	..	..	..	13 0 0	12 0 0	
Third class brickwork in walls good bricks, set in mud, ditt	..	..	..	8 0 0	10 0 0	
First class brickwork in arches dressed faces, including cent up to 16 feet span, ..	..	..	..	..	..	
Undersunk brick masonry in including sinking, ..	..	..	..	..	..	
Plastering.						
Best lime Plastering for ex 0 walls, ½" . .. 0	..	1 12 0	..	1 8 0	3 4 0	
White washing, 2 coats,	0 2 4	0 2 9	..	..	..	
Color washing, ditto, ..	..	..	..	..	..	
Roofing						
(Exclusive of timber fram						
Flat pucka terras Roofing, o 0 course of flat bricks or tiles,) 0	..	12 1 0	..	..	17 8 0	* Inclusive of timber work.
Thatched roofing 9" thick,	4 8 0	1 9 0	..	..	..	† 6" Thatching.
Tiled roofing, common country set in mud on bamboo fram) 0 and mats, ..	..	..	..	..	..	
Ditto, ditto, set in mortar, o layer of flat brick, ..) 0	..	..	..	..	..	
Corrugated Iron roofing,	..	..	..	..	..	
Flooring						
Pucka terras Floor, of best q over 2 courses of brick,	4 0 0	..	..	16 0 0	23 0 0	

	S								
	Dinapore.	Shergotty.	Hazareebaugh.	Burrakur.	Burdwan.	Midnapore.	Balasore.	Cuttack.	REMARKS.
Flat bri and l Brick-o	..	..	..	..	..	..	..	..	
rubbe joints cours Slate fl	..	10 0 0	..	..	..	..	..	5 0 0	
	..	..	..	..	..	..	..	..	
Saul tin roofs, cludin clusiv Pannell	.	2 0 0	..	..	2 8 0	..	..	1 8 0	
	..	1 0 0	..	..	..	..	..	..	
Best En ges, bc Country	..	17 0 0	..	..	..	..	..	..	
	..	..	..	..	..	..	..	..	
Painting Red oi	.	3 8 0	..	3 0 0	..	..	..	2 0 0	

P. H. TROTTER,

Deputy Controller and Examiner of P. W. Accounts, Bengal.

LIX.

BARRA BRIDGE—LAHORE AND PESHAWUR ROAD.

Designed and Built by LIEUT.-COLONEL, A. TAYLOR, R.E., *Superintendent Lahore and Peshawur Road.*

THE Barra River, which meets the Lahore and Peshawur Road about 7 miles to the west of Peshawur, formed the chief obstacle to traffic on the Trans-Indus section of the road. Its drainage area can only be guessed at, as it runs for the greater part of its length through country which no European has ever visited; but it probably drains the greater portion of the mountainous district of Teerah, extending almost as far as Caubul. From the point where it issues from the Khyber Pass, at Fort Barra, to its junction with the Caubul River, it runs on a ridge which it seems to have raised for itself by successive deposits. This peculiar formation renders it very mischievous to the surrounding country, which, during the summer rains, it lays under water for miles.

A strut and strain timber bridge, resting on piles and wooden piers, had been originally sanctioned by the Government; but the unheard of behaviour of the river caused the design to be altered to the present plan. Every arrangement had been made for commencing the work; when the river put a stop to further proceedings by carrying off the pile engine in the middle of the night; and with it the Assistant Engineer in charge, who was unwary enough to be caught by the sudden rush of waters, which he describes as having come down like a wall. Engine and Engineer were stranded some six miles down the

river, both coated with whip grass to such an extent, as to warrant the latter's opinion that wooden piers would never stand in the Barra. He thought no wooden framing could have stood the weight and vibration of such a mass of grass, branches, &c., as would certainly have caught in the *wales* and cross braces of the piers. So is experience acquired in India; and this little incident is a good commentary on the *Peculiarities of Indian Engineering.*

This opinion was confirmed by the great flood of July 1861, which happened only a few days later. The river on that occasion rose 18 feet in 5 minutes; and was observed to have a surface velocity of 15½ feet a second, or over 10 miles an hour. A timber superstructure was therefore decided upon, which should obviated the risk of the scour, consequent on checking such a current; and work was commenced upon the left pier foundation.

The soil consisted of alternate thin layers of very stiff clayey silt, and loose sand, for a depth of 18 feet; then came a bed of sand 8 feet in thickness, overlying a stratum of clay. It was therefore necessary to excavate down to the thick layer of sand by open foundation, and then, through it, to countersink masonry wells to the solid clay below, a total depth of 26 feet. Although the river was only ankle deep at the time, the soil was so saturated with water, that the two pumps, which were alone available, were found quite inadequate to keep the foundations dry; and the work was stopped, until 12 churusses or water bags, each worked by 6 men, could be rigged up. A depth of 12 feet was reached by working night and day; when a land spring was tapped, which put an end to any chance there might otherwise have been, of doing the work by the help of churusses alone. A plan was then suggested, which succeeded so well in this case, and has since proved so useful in many similar works, that a short account may not be amiss. Two wheels were taken off a horse cart, and fixed 5 feet apart, on an axle projecting about 3 feet on either side. Battens were then lashed to the ends of corresponding spokes, projecting 2 feet beyond the tires, and forming a kind of drum. This machine, on being turned by 2 men stepping on the battens as on a tread-mill, brought up the water by means of two chains of pots, passing over the projecting ends of the drum and discharging into troughs placed on the axle; a cross bar on two up-rights being provided for the men to hold on

by. This machine, requiring 4 men to work it during the day, and 6 men during the night, does more work than 6 churusses, and costs very little in making. By means of three such drums the water was kept under, and the western pier completed. The excavation was twice filled up, during the progress of the work, by floods in the river, which it would have been impossible to keep out by any means short of a regular cofferdam.

Work was now commenced on the eastern pier, which was completed in half the time, and at one-sixth of the expense of the western. A small irrigation canal which ran along the high bank of the river, was utilized into turning a water-wheel 12 feet in diameter, connected to a drum 7 feet in diameter, carrying two chains of very large pots. The chain was made in pieces of 4 feet in length, connected by hooks-and-eyes, so as to allow it to be lengthened or shortened with ease to suit the level of the water; an operation otherwise productive of much labor and waste of time. The wheel was found to work best, when doing from 8 to 9 revolutions in the minute, as a higher velocity did not allow the pots time to empty themselves properly into the trough. The work done averaged from 1,200 to 1,600 cubic feet of water raised 18 feet in the hour; and more might have been done, if required, by putting on a heavier chain of pots and turning on more water. The cost of setting up the whole machine did not exceed 70 Rs.; the wheel being very roughly made of slab planks and refuse wood; and the saving effected by it was over Rs. 2,000. Hence it appears, that in cases where much water is met with in foundations, it may often be true economy to spend even a considerable sum on obtaining water as a motive power to the pumping arrangements; either by damming up the river itself so as to obtain a fall, or by cutting a channel to bring the water from other sources. It may be said that this is a self-evident statement; but the little use made of the enormous water power available throughout India, shows that the self-evident truth will bear repeating, as it is so very seldom acted upon.

The springs which gave so much trouble by swamping the foundations, were of two kinds. The first, which looked exactly like, but were not really, land springs, were generally due to some local cause, such as water running near the excavation, &c. These could either be entirely stopped, or very much checked, by cutting a trench close to the

supposed source of supply, and between it and the excavation; or if this did not succeed, by blocking up the spring; which, if of this nature, was seldom so strong as to force its way out in another place.

A few drainage cuts, in the high ground above the excavation, materially lessened the influx of water; an unlooked for result, considering the work was being done in the bed of a river.

The real land springs, which could always be recognized by the high temperature of the water, were much harder to deal with, and could only be checked in very hard clay soil. This was done, by driving pointed slab planks close together some 4 feet into the ground round the spring; then building a sort of masonry well as high as the water would rise, and filling it up with quick setting mortar and good clay. But this plan did not always succeed; and it was generally found best not to interfere with the land springs; as, if blocked up, they undermined and brought down the shores and planking supporting the sides of the excavation, and did a vast deal of mischief.

The wells were sunk in the usual manner, but were vaulted over with segmental domes connected by cross arches, a quicker method than filling them with concrete, and then building up solid, as usually practised. This would have required some fifteen days for the concrete to settle; and no stone slabs were procurable of sufficient size to stretch from one well to the other. The bricks for the domes were previously cut on a centreing on the ground. The tops of the wells were strongly bonded with hoop iron, to resist the thrust of the vaults and cross arches, which are shown in detail in the plan.

The centering for building the plank ribs, consisted of a number of long stout timbers (which were afterwards used up as roadway beams) laid at equal distances on the ground, in the direction of radii of the curve, and carefully levelled. Any short spare timbers, not less than 10 × 8 inches, that could be obtained, were then roughly dressed to the required radius on their outer side, and connected together by square lap joints so as to form one continuous curve. These were further kept together by $\frac{3}{4}$-inch bolts passing through the lap joints, and the extremities of the long timbers, into which they were slightly notched to prevent the bolts being bent by lateral pressure. The curved outer face of the short pieces was then carefully dressed and planed to the required ra-

dius, and formed a centering, on to which the planks were bent with screw clamps. Notches were cut on the curved surface, opposite each joint in the rib, sufficiently large to admit a wrench, by which the nuts were screwed home. The same centering served for all the trusses ; those of least curvature being built first. In such cases it would, however, always be better to raise the centering on brick pillars some 3 or 4 feet from the ground; as this would allow the workmen to fit the lower face of the rib as accurately as the upper. There would then be no need to turn the rib on itself to plane and adjust its lower face—a great advantage—as plank bows are very liable to be damaged by the strains produced by their own weight, if not very carefully supported at their extremities. They should be moved as little, and as carefully, as possible before being permanently fitted on to their tie-beams. To prevent the ribs from flattening out, they were kept screwed on to the centering, and thoroughly wetted, for a few days after being bolted together. As the low centering would only admit of this being done to the upper face of the bow, the unequal expansion caused it to warp; and it is very probable, that the tendency so occasioned, may spoil the look of the bridge, when time and weather have loosened the joints of the cross and side bracing.

In order to allow for the straightening of the rib when taken off the centering, the latter was built of a sharper curvature than the arch was intended permanently to retain. The tendency to flatten, is however much less than might be expected, and no difficulty was experienced in keeping the bows of the proper shape. The radii of the centerings were made shorter than the proper radii, by ¼ of an inch to every foot of the intended rise in the completed arch; and in every case this allowance was found to be quite sufficient. 35 feet 6 inches was found to be the least radius to which 3-inch deodar planks should ever be bent; as none but the very best would take that curve. 2½-inch planks would have been employed, were it not that the strength of a laminated arch, as compared with that of a solid rib, diminishes almost in the ratio of unity to the number of layers into which it is divided.

Many different methods were tried for bending the planks, but the following plan, which was very economical as not requiring a

steaming apparatus, was found less injurious to the fibres of the wood than any other. The planks were wholly immersed in water for eight or ten days; then taken out, placed on edge before a bright chip fire, and oiled on both sides until well heated throughout. They were then bent on to a curved gauge, by means of a rack-stick and rope looped over their ends, without giving any signs of straining. On cooling, they retained the form so given them; and by soaking half an hour in water, and repeating the process of heating and oiling, could be fitted on to the centerings with the greatest ease.

It is doubtful, whether iron hoops shrunk when hot over the ribs, would not answer better than bolts to connect the layers of planking. Hoops would not, in practice, be as convenient as bolts, if it were necessary to take out or renew a plank, and might not make so stiff an arch; but they would not weaken it by bolt holes near the joints. A combination of both would perhaps be best—hoops for the outside and bolts for the inside joints. The joints of an outside plank can never, by means of bolts alone, be prevented from starting from each other and from their underlying planks, after a little exposure to the weather. A broad strap over the joint would quite prevent this; and the rib would not be weakened by four bolt holes, passing through it at its weakest points.

The following points were noticed in the construction of the tie-beam, which may be of some use. The scarf shown in the drawing might with advantage have been altered to a plain fish-joint with stout strap irons. This was actually done in one of the smaller ribs; and was found on trial to act better than the scarf, which showed a great tendency to split up at its angles. Hard wood keys, $1\frac{1}{2}$ inches square, introduced at intervals between the two pieces of the tie-beam, prevented their sliding on one another under unequal strains, and took the lateral pressure off the connecting bolts. The corners of the notches, cut for the reception of the hard wood abutting blocks, were secured from splitting up under the thrust of the arches, by pieces of angle iron let into the wood.

The bridge was tested by a dead load of (it is believed) 200 lbs. to the superficial foot of roadway; which it bore without injury. Owing, it is supposed, to the strength of the arched ribs not being at

first, fairly brought into play, the deflection under the half, was greater than that under the whole of the load.

All the timber in the bridge, with the exception of the sheeshum abutting blocks, was obtained, at great trouble and expense, from the deodar forests of Kashgar ; a wild and unexplored country, some 150 miles north of Peshawur. The timber trade so created, although entirely in the hands of native merchants, is now very extensive, and bids fair ere long to rival that on the Jhelum and the Chenab.

Specification.

The Bridge consists of 3 spans. The two end ones having a clear waterway of 53 feet, and the centre span a waterway of 74 feet. The piers and abutments are of brick-work founded at the depth shown. The timber work to be entirely of deodar free from sap wood.

Wall Plates.—The lower pieces are 10 × 6 inches scantling. The upper pieces rest on them and are 10 × 8 inches scantling.

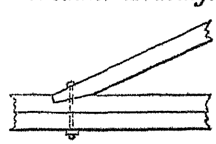
Corbels.—Are notched out and let down on to the wall plates to the extent of 2 inches. The keys connecting the corbels and tie-beams are of seasoned sheeshum or Kow wood.

Tie-beams.—Are shown in the drawings in full detail. All trenails are to be baked before they are used.

Abutting blocks.—Against which the arches and the cross braces abut, are of seasoned sheeshum.

Roadway Beams.—Are let on to the tie-beam to the depth of 2 inches. The beams which project and carry struts to steady the vertical frames are to be secured to the tie-beams by $\frac{3}{4}$-inch bolts. All other roadway beams, excepting the last over each abutment, merely rest on the tie-beams. They are kept in place, by the 2-inch deep notches at each of their ends, and by the planking which is spiked on to them.

Weather Bracing.—None is provided for in the two end arches; in the centre span two timbers 8 × 6 inches are introduced at each end, secured to the tie-beams by 1-inch bolts and proper joints, as shown ; and supported each at its centre by a bolt passing through a roadway beam.



Roadway Planking.—The spikes to be 9 inches long; two spikes to be used at each end of every plank. One spike is to secure each plank to every roadway beam that it crosses.

Wheel-guard.—Different lengths to abut against each other with square ends.

Cross Braces.—To be stepped into the hard wood blocks with tenons 2 inches square and 1½ inches deep, and to be secured to each other, where they cross, by a ½-inch bolt.

Arches.—Full details are given in the drawings. The surface of the planks to be tarred before they are finally put together in the arch.

Railing.—Is secured at intervals to the cross braces and arches.

Vertical Frames.—The posts are bolted to the tie-beams and to the arches, and fit into the cap pieces, with mortice and tenon joints secured by an iron strap.

Painting.—The railings, railing posts, and struts, are to be painted.

Tarring.—The beds of the hard wood blocks, all touching surfaces, where not exposed, surfaces of junction between corbels, wall plates, and tie-beams; and touching surfaces of tie-beam itself, &c., to be tarred.

Tie-Rods.—The heads to rest on the tops of the arches over an iron washer. Under the nut, a piece of hard wood 12 × 6 × 4 inches, is inserted to distribute the support over the tie-beam. A washer to be inserted between the nut and the hard wood.

Stone Posts.—To protect the ends of the central arch over the abutments; two stone posts of 9 inches diameter are let into the ground.

ABSTRACT OF ESTIMATE.

c. ft.		RS.	A.	P.
1,15,480·	Excavation of dry soil, at Rs. 4 per 1,000,	461	14	9
61,200·	„ wet soil, at Rs. 40 per 1,000, ...	2,448	0	0
169·3	Deodar neem chuck, at Rs. 2-4 per c. ft.,,	380	14	10
191·2	Well sinking, 8 ft. dp., at Rs. 25 per 100,	172	12	10
13,000·60	Brick-work, at Rs. 24, per 100, ...	3,120	2	3
12,778·08	Superstructure, &c., at Rs. 24 per 100,...	3,066	11	10
1,090·75	Stone capping and guard blocks, at Rs. 1 per ft.	1,090	12	0
5,574·08	Wood-work deodar, at Rs. 2-4 per. ft.,	12,541	11	3
131·65	Hard wood work, at Rs. 4 per ft.,	526	9	7

ABSTRACT OF ESTIMATE.—*(Continued.)*

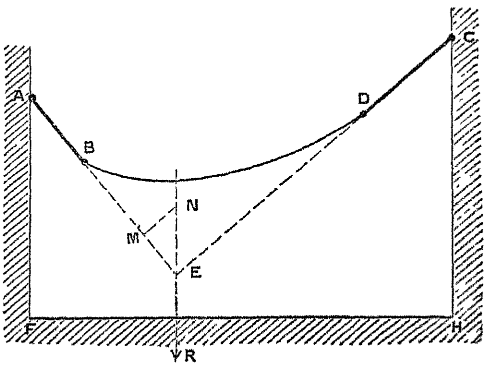
lbs.			RS.	A.	A.				
6,588 24	Iron work, at Rs. 20 per 100 lbs.,	...	1,317	10	4				
s. ft.									
31,363 31	Tarring, at Rs 2 per 100, ...	...	627	4	3				
2,432·	Painting, at Rs. 5 per 100, ...	...	121	9	7				
	Allowance for work commenced on former designs, but unavailable for this one, ...	...	130	0	0		26,006	1	6
	Add Contingencies at 5 per cent.,	...					1,300	4	11
	Grand Total Rupees,	...					27,306	6	5

ALEX. TAYLOR, LIEUT.-COL., R.E.
Supdt. L. and P. Road.

CALCULATION OF THE STRAINS ON THE DIFFERENT TIMBERS IN A BOWSTRING GIRDER.

The conditions of equilibrium of a rib, are exactly similar to those of a chain; both being under an uniform vertical load. Most of the calculations on such chains or ribs may be said to depend on the following property, which can be proved mathematically, but will now merely be stated.

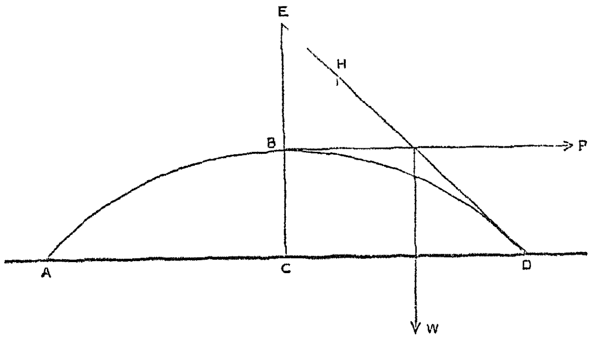
AB, CD, are two straight weightless rods moveable round hinges



at A and C, in the walls AF, CH. Let BD be a cord attached to their extremities, and loaded either with constant, or with variable loads. In the position of equilibrium of the system, the rods AB, CD, will be tangents at B and D to the curve assumed by the cord whose tensions at those points, will act in the direction of AB and

CD. The resultant of all the forces acting on the cord BD will pass through the intersection of the tangents at E. The tensions and resultant are also represented in magnitude by the sides of a triangle drawn parallel to their directions, such as NME.

From this property it can now easily be proved, that the curve of equilibrium under an uniform load is a parabola; such that ED being



a tangent at D (see figure) EB = CB. The triangle CED will also represent the magnitude and direction of the forces keeping the arch in equilibrium.

If then W be the weight of the loaded half arch, P the pressure at B, H the pressure at D in the direction of the tangent ED, we have—

$$W : P : H :: EC : CD : DE$$

$$\therefore P = \frac{W\ CD}{EC} \text{ and } H = \frac{W.\ DE}{CE}$$

(α) $\therefore$ Pressure at the crown $= \frac{W.\ CD}{EC} = \frac{W\ CD}{2\ CB}$ and tension of the beam $=$ horizontal component of $H = H \cos EDC = \frac{W.\ DE}{CE} \cdot \frac{DC}{DE}$.

(β) .... $= \frac{W.\ CD}{2\ CB}$ also.

The rib and the tie-beam should therefore be of the same scantling, were it not that the latter besides tension is acted upon by a cross strain.

To allow for this cross strain, the scantling of the tie-beam is calculated from the formula,

$$f' = \frac{H}{b\ h} + \frac{6\ M}{b\ h^2} \quad \text{.........\ ....} \quad (\gamma)$$

Where f' = The safe crushing weight of the wood used.

H = Tension of tie-beam.

$b \times h$ The scantling of tie-beam.

$M =$ Bending weight on each section of the tie-beam.

To apply these results to determining the scantling of the main rib of the centre span of the Barra Bridge, we have—

Width of roadway, 10 feet.

Length of roadway, 74 feet.

Weight of roadway per s. foot, 280 lbs.

Height of truss, 16 feet.

∴ Whole weight on centre truss

$$= 74' \times 10' \times 280 \text{ lbs.} = 2{,}07{,}200 \text{ lbs.}$$

and $W =$ Weight on half arch $= 1{,}03{,}600$ lbs.

∴ From (a)

Pressure at the crown

$$= \frac{W.CD}{2\,CB} = \frac{103600.37}{32} = 119{,}787 \text{ lbs.}$$

and a square inch of deodar can resist a pressure of 700 lbs.

$$\therefore \text{ Area of rib} = \frac{119787}{700} = 171 \text{ square inches.}$$

But, as 700 is rather a high co-efficient, the scantling of the rib is made, $18'' \times 10''$ or 180 square inches.

Again, from equation β,

Tension of tie-beam $= 1{,}19{,}787$ lbs.; and the weight on each section between the suspending rods

$$74' = \times 10' \times 280 \text{ lbs.} = 20{,}720 \text{ lbs.}$$

which is equivalent to a bending weight of 10,360 lbs. at the centre of the section. Let the depth of the tie-beam $=$ 10 inches, then if b be its width in inches, equation γ becomes

$$700 = \frac{119787}{10\,b} + \frac{610\,.\,360}{100\,b}$$
$$= \frac{1260030}{100\ b}. \text{ whence}$$

$b =$ 18 inches and 20×10 inches, is actually given to compensate for bolt holes, weak joints, &c.

For the diameter of the suspending rods; 220 lbs. being assumed as the weight per superficial foot of roadway, exclusive of the weight of the rib.

Weight on each rod

$$= 220 \text{ lbs.} \times 10 \text{ feet} \times 7{\cdot}4 \text{ feet.}$$
$$= 16{,}280 \text{ lbs.}$$

and tensile strength of wrought-iron being 12,500 lbs.

Required section of iron $= \frac{16280}{12500} = 1{\cdot}3$ inches.

For the dimensions of roadway beams, 2 feet from centre to centre, and 11 feet 6 inches long. The severest probable test on these joists, would bring a weight of $1\frac{1}{2}$ tons on a foot run of the bridge. Hence the joists should be able to support a weight of $1\frac{1}{2}$ tons at their centre. If the joist were 8 inches deep, the breadth b would be found by the equation

$3360 = \frac{b \cdot \delta^2}{11' \, 6''} \cdot 115$ (co-efficient for transverse strength of deodar).

Whence $b = 5{\cdot}25$ inches; and the scantlings may for safety be increased $\frac{1}{5}$th, or 10×6 inches, the dimensions actually given.

For the scantlings of the diagonals, the following formula is used—

$$T = \frac{w' \, s}{k} \cdot \frac{n\,(n+1)}{2\,N}$$

Where

T = Greatest thrust on diagonal.

N = Whole number of divisions of roadway.

n and $n + 1$., The numbers of the rods between which a diagonal is situated.

s = Length of brace.

k = Difference of level of its ends.

w' = Greatest travelling load on the post.

To determine the proper scantling for the centre diagonal braces, we have—

$N = 10$.

n and $n + 1 = 4$ and 5, respectively.

$s = 17$ feet.

$k = 16$ feet.

$w' = 1\frac{1}{2}$ tons $= 3{,}360$ lbs., the greatest likely travelling load acting on the brace.

Hence

$T = \frac{3360 \,.\, 17}{16} \cdot \frac{4 \,.\, 5}{2 \,.\, 10} = 3570 =$ thrust on the diagonal.

The brace being 34 times as long as its thickness; the co-efficient of crushing should be for deodar about $\frac{700}{4}$ or 175 lbs.

Hence proper sectional area $= \frac{3570}{175} = 20$ square inches; or rather less than the section $6'' \times 4''$ which is actually given to the braces.

J. Browne, Lieut., R.E.

INDIAN BARRACKS.

In an article on Anglo-Indian Architecture, in Vol. I., I expressed an opinion that the style of building usually adopted in the Upper Provinces for our dwellings, was ill adapted to the climate. Having lately been called upon to act as member of a Committee on the Ventilation and Cooling of Barracks, I have been led further to consider the question of the best form of barrack, and now venture to offer the following suggestions on the subject.

The general fault of all Barracks that I have yet seen is, that they are very hot in summer, and cold and *draughty* in winter—that there is no proper system of ventilation;—that the men have virtually to live in their bed rooms, in an uncomfortable fashion, and without any privacy;—that they are very expensive and exceedingly ugly.

Now, there is little doubt that the present fashion of barracks arose from our first tropical stations being on or near the sea coast, in which numerous doors are required through which the refreshing sea breezes may sweep through the building. But it is *primâ facie* unlikely that buildings erected after the same fashion in a totally different climate such as that of Hindostan, should answer their purpose. For several months in the year it is necessary in these provinces to exclude the external air all day long, and (but for the sake of ventilation) through the night too, and when to the heat is added the abomination of a dust-storm, not to mention the normal plague of *flies*, the discomfort of the present arrangement is indescribable. The best fitting door will hardly exclude the dust, and half the doors won't shut, while the other half have broken panes of glass.

It would, therefore, in the first place seem desirable to reduce the number of *Doors*, to what is absolutely required for ingress to, and egress from, the barrack; so that there should be as few entrances as possible for the hot air in summer, and the cold air in winter; upper windows or sky-lights being employed for light. These may be made to open, and should be defended from the direct rays of the sun by venetians, but they are primarily for light and not for ventilation, which should be independently arranged.

Next, as to the *Walls;* if the cost were not too great, I would make them 8 or 10 feet thick, so as to be absolutely impervious to the external heat. But I believe the same end may be answered by using walls of the ordinary thickness, only *making them hollow.* This is so common a construction now in England, where its advantages in excluding damp are well understood, that it is surprising it has not been tried in India for excluding heat as well as damp. Hollow walls may be made of ordinary bricks, or with the help of bricks specially moulded,* as shown in the annexed plate, the latter arrangement being copied from the Civil Engineer's Journal for 1862, where its use is explained in the construction of the Dover Railway Station. Hollow *bricks* might also be tried, as nothing but actual experiment can determine which is the coolest construction.

Whether open verandahs can or cannot be dispensed with for such walls must also be settled by trial. The principal use of verandahs is undoubtedly to shade the doors, but it is proposed to dispense with most of these; they do certainly defend the lower part of the walls from the sun, but it is *only* the lower part; and as for convenience, it is well known that in the hot weather they are far too hot to be used.

On such walls I would not put an ordinary wooden trussed roof covered with thatch or tiles; the one is inflammable, the other leaks —both are perishable. A hollow arched masonry roof would be

* I have had some of these bricks made and burnt at Roorkee without any trouble. Perforated bricks are also common in England, the perforations being simply to secure a more uniformly burnt brick by allowing the flame to reach the inside through the perforations.

better than either, and the Syrian roof, or the improvement on it, used in Scinde by Col. Fife, (see p. 411, Vol. I.,) might be employed with advantage.

For ventilation, let the floors be *hollow*, the plinth of the building being raised above the ground on arches, forming a basement story,* which might be used for Wash-houses, Privies, and Store-rooms. In the centre of this basement may be placed thermantidotes or fans, by which a continuous current of air will be forced up through perforations in the floor, the foul air being allowed to escape through the domed roof, or by a perforated cornice at the springings, aided if necessary by ventilating shafts with furnaces or exhaust fans (*see* "Ventilation of Barracks" in the present Number.) Of course the fresh air will be cooled, when necessary, by passing it through tatties, or it may be warmed if required.

So much for the construction of the barrack. As to its arrangement, there should be a central dining hall, which would also be the reading room and general living apartment. In the long sleeping wards, I would have wooden and canvass partitions, 8 feet high, giving each man a small room which he would feel was his own (Addiscombe readers will know what *kennels* are). In the cold weather there could be no objection to them. In the hot weather, they might, if necessary, be removed, but I do not think with the ventilation I have proposed, that they would be objectionable. If punkahs are used it might be better to lower the partitions to 7 feet; but punkahs could I hope be dispensed with in such a building. They are expensive and troublesome, and give the men sore eyes, and all that is necessary is to employ thermantidotes of sufficient power below, to blow in a proper quantity of fresh cool air. The Barrack Commission in England give 20 cubic feet per man per minute as the quantity required. For a whole company barrack then 2,000 cubic feet per minute are wanted, which would be supplied by an ordinary 6-feet thermantidote, making 60 revolu-

* The basement might perhaps be partly sunk with advantage below the ground level for the sake of coolness; forming a series of *taekhanahs*, such as are common in Native Forts; they are very cool in hot weather.

tions per minute.* The Agra jail is ventilated in this manner, and the arrangement is said to be highly successful.†

The arrangements recommended above are shown in the accompanying design. I don't say it is a very handsome building, and doubtless it might be improved, nor would it answer for a climate different from that of Hindostan, where the thermometer ranges from 30° to 130°, where the night is often as hot as the day, and where dust-storms and hot winds are common. The addition of verandahs might also be found necessary, and I have partly shown the arrangement I would in that case propose, but I believe for a barrack in Upper India such a construction would be cooler, healthier, more comfortable, and more durable, while it would at least be not uglier than its predecessors.

Specification.—Each Barrack to accommodate a whole company, (nominally 100 men,) to consist of four Wards 75 × 25 feet, radiating from an octagonal Dining Hall 30 feet wide. The Walls to be of hollow (brick) masonry, 2½ bricks thick, the Roofs semi-circular arched, and also hollow except that of the central hall, which will be of large tiles supported on iron trusses. The Basement story to be as shown in section, and to carry the flooring of the wards and hall on semi-circular arches, perforated to allow of a free current of air passing up. Below the central hall will be powerful Thermantidotes, driven by bullocks, to blow air down the passages under the floors; ‡ and from this central space below, the punkahs (if required) can also be pulled. In the basement below the wards, will be situated the wash-houses, baths, privies, and store-rooms.

If Verandahs are required, an ordinary arched masonry verandah

* The Reform Club in London has a similar apparatus driven by a 5-horse power steam engine, and supplying 11.000 cubic feet of air per minute.

† I think it is worth a trial, whether the ordinary form of thermantidote might not be superseded by a piston and cylinder to drive in cool air, as mines are ventilated in England, and furnaces are usually blown. A steam engine of 3 to 5-horse power, ought to do this and pull punkahs as well, and even if bullock power be employed, the arrangement might be adopted if more efficient than the usual one.

‡ If the central pillar, on which the groined arches abut, should interfere with the working of the ventilating apparatus, iron girders might be substituted to carry the floor of the Dining Hall.

will be provided for the basement story, supporting cast-iron pillars with a tiled roof for the upper story, as shown in the plan.

Stair-cases where shown in the plans. The upper windows to be fitted with venetians,* and a louvred ventilator to be provided all along at the level of the cornice. A fire place is shown at the end of each ward, but in winter the thermantidotes might be employed to drive in warm instead of cold air.

The Cost of such a Barrack will of course chiefly depend on the price of brick and mortar; the barracks at Nowshera (see Vol. I., p. 132) cost Rs. 72,447, besides the cost of the Iron roofing, which if added would swell the total probably to Rs. 90,000. Nor do I think that barracks of the ordinary kind could be built as a rule under Rs. 800 per man, besides the wash-houses and privies, which are usually separate. At an average rate for masonry all through of Rs. 22 per 100 cubic feet, (and there would be a great saving of bricks by the hollow construction), the cost of the proposed design would be Rs. 50,000 (500 Rs. per man) without verandahs, or Rs. 60,000 with verandahs.

Since writing the above, I have seen the suggestions for Indian Barracks, prepared by the Barrack and Hospital Commission in England. The general form of double-storied barrack there given, would doubtless be very good for a West Indian station, or for a place on the Indian sea-coast; but for the climate of Upper India its numerous large windows and doors would make it as objectionable as those generally constructed. Nor would the ventilating shafts work, when the external air is hotter, and therefore, lighter than the foul air which is meant to be extracted. Under such a condition, a powerful artificial current is necessary in aid of the natural currents through the ventilators. Regarding the methods of cooling the air, the Commissioners say—

"The thermantidote is correct in principle, but of all the methods of moving air, that by means of a fan wheel used in the thermantidote is the most costly, on

* The glazed frame inside should be moveable on a central hinge; the venetians must also be workable from the inside.

account of waste of force. Dr. Arnott's ventilating air pump, either in the form of a light metal gasometer, or of a large light piston swinging like a punkah in a fresh air chamber, with suitable valves for ingress and egress of air and means of cooling, would be the nearest approach to an economical and effective thermantidote. The expenditure of force required to move large masses of air by Dr. Arnott's contrivance is very small indeed.

"The cheapest source of cold for cooling air in India is evaporation. And air so cooled should be allowed to enter barrack rooms and wards, not in rapid currents, but in large slow moving masses. The cheapest mechanical method for moving large masses of air is Dr. Arnott's ventilating air pump.

"We would suggest this whole subject for consideration in India, where improved methods of cooling air could be tried to an extent for which there are not facilities in this country."

The kind of Roof recommended, consisting of tiles laid on boarding, would be objectionable in this part of the world—the extreme changes of temperature would certainly warp the boarding and crack the tiles, and make the roof leaky. One object in the design above given is to dispense with a perishable material like wood in all the essential parts of the building.

The recommendations given for hollow walls and a basement story correspond with what is proposed above, but the use of the basement for ventilation as well as for dryness is not suggested. Indeed, the recommendations of the Commissioners lay such stress on the evils of dampness, that it is clear they had the climate of Bengal in view, rather than that of Upper India. Giving every credit to the value of many of the suggestions in the Report, it does not appear that the specialities of the climate of Hindostan have been taken into account,* and that the best kind of barrack to suit those specialities remains still to be devised.

J. G. M.

* Judging from the names it would appear that only one Member of the Commission has ever been in this part of India, and his attention was always directed to totally different subjects.

No. LX.

UMRITSUR CLOCK TOWER.

Estimate framed by J. GORDON, ESQ., C.E., *Executive Engineer, Civil Works, of the cost of erecting a Clock Tower in the City of Umritsur, and improving the site by a terrace wall and steps.*

REPORT.

THE first plans and estimates for this work were prepared without reference to any particular site, and nothing more than a plastered brick-work building was contemplated.

The present conspicuous site having been determined on, it was considered advisable to enlarge the base of the tower so as to allow more space in the lower part of the building, and afford a more convenient spiral stair; which necessarily increased the height in proportion, adding thereby very considerably to the expense of the work, but insuring a very superior structure.

The total outer width of base on the first plan was only 24 feet, and the proposed height 100 feet. On the present plan the width (at the lower buttress) is 32 feet, giving in the same proprtion a height of 133 feet.

The site being the highest point in the city, about 10 feet above the surface of the country, the total height of the tower above the marble tank will be—

Height to stone finial, ...	133 feet,
„ of gilt finial, ...	4 „
„ of site above level of ground, ...	10 „
Total height, ...	147 „

being about 6 feet higher than any of the city buildings.

The foundations of the tower are unavoidably heavy, as the ground is artificial and unsound for a depth of 12 feet, this circumstance also adds considerable to the extra cost of the building.

It is proposed to construct the building of the *finest description of brick-work*, with dressings and ornamentation in red sand-stone, this being the only practicable way of producing a work worthy of the site, and in harmony with the surrounding objects

The stone work will be the most costly item in the estimate;* but I feel confident that the result will give satisfaction, as the stone-cutters are very skilful workmen.

The plan of site shows the proposed terrace wall, with flights of steps 32 feet wide, leading to the terrace and tank.

It is considered that this will produce a very improved effect, and give a finish to the entire place, as a frame to a picture.

An arched verandah,† for visitors and spectators on occasions of illuminations, has also been introduced, which will command a good view of the temple and towers. On the opposite side of the terrace, a house in the same style is being built from the plans prepared recently.

The steel bell and new dials have been shipped from England; the bell being 3 feet diameter, will be heard at a distance of four miles. The dials are of the most improved plan, having the figures and hands enclosed between two plates of glass (one semi-transparent) by an iron ring, which arrangement completely prevents injury from dust or rain.

The motto selected for the clock is "pereunt et imputantur," taken from Exeter Cathedral, and suggested by Mr. L. Griffin. White marble tablets will be inserted in pannels in the doorways for any names, records, &c., which may be considered necessary.

As a finish to the design, I hope to be able to get sanction for four figures for the niches round the faces of the clock, which can be done after completion of the building. The Lahore Exhibition may produce some work of art which will perhaps assist in carrying out this idea.

A great difficulty having been experienced in procuring first class bricks, necessary for the face work of the tower, the working establishment has been for some time engaged in the preparation of cut stone dressings and pillars for the lower section of the building, which is in a very advanced state.

* The cost of undressed stone at Umritsur is from Rs. 3 to 3-8 per cubic foot.

† This verandah will conceal an unsightly blank wall.

Red sand-stone has been procured, in great part in the city of Umritsur, and I apprehend no difficulty in procuring a sufficient quantity for the entire work.

A Clayton's brick compressing machine has been procured for the manufacture of face bricks for city works, and bricks are now being moulded with it, which will be ready in a few weeks.

ABSTRACT OF ESTIMATE FOR TOWER.

		RS.	A.	P.
c. f.				
15,068	Excavation for foundations, at Rs. 5, ...	75	0	0
3,483	Concrete in foundation, at Rs. 8, ...	103	0	0
10,231	Pucka masonry in foundation, at Rs 20, ...	2,064	0	0
4 616	„ dressed in steps, at Rs. 25, ...	1,154	0	0
260	„ brick-on-edge, at Rs. 30, ...	78	0	0
27,738	„ superstructure, including scaffolding, at Rs. 35,	9,708	0	0
1,142	Cut stone dressings and finials, at Rs. 7, ...	8,008	0	0
s. f.				
3,684	Plastering part of interior and painting ceilings, at Rs. 5, ..	184	0	0
300	Encaustic tiles for floor, at Rs. 0-8-0 per foot, ...	150	0	0
8	Marble tablets, at Rs. 10 each, ...	80	0	0
	Lettering 8 tablets and cutting 8 shields, at Rs. 12 each, ..	96	0	0
s. f.				
363	Windows, including painting wood work, at Rs. 1-4-0, ..	454	0	0
150	Timber flooring, at Rs. 50, ...	75	0	0
r. f.				
77	Iron spiral ladders, at Rs. 2-8-0, ...	192	0	0
10	1½-inch iron for spire,..			
20	¾ „ „ for pinnacles, ...	50	0	0
1	Iron ring (1½-inch), 36 feet circumference, ...			
5	Iron finials, gilt, at Rs. 30, ...	150	0	0
100	Brass letters, gilt, at Rs. 1 each, ...	100	0	0
		22,703	0	0
	Contingencies at 5 per cent., ...	1,135	0	0
	Total Rupees, ...	23,838	0	0

Estimate for Four Glass Dials, 5 feet diameter, and Steel Bell, 3 feet diameter.

4	Dials, ...	1,250	0	0
	Packing, ...	150	0	0
	Freight and insurance, ...	820	2	8
	Bell, including carriage, &c., ...	450	0	0
	Total Rupees, ...	2,670	2	8

Terrace Wall, Steps and Arcade.

			RS.	A.	P.
c. f.					
7,861	Pucka masonry in steps and terrace wall, at Rs. 25,	..	1,965	0	0
18,800	Earthwork, at Rs. 4, ...	..	75	0	0
5,866	Pucka masonry in arcade, at Rs. 25, ...	..	1,450	0	0
s. c.					
2,160	Plastering, at Rs. 5, ...	..	108	0	0
	Total Rupees,	..	3,598	0	0
	Total cost of Tower, Rupees,..	..	23,838	0	0
	Dials and Bell, including freight, &c., ...	..	2,670	0	0
	Terrace Wall, with steps and arcade, ...	..	3,598	0	0
	Grand Total Rupees, ..	...	30,106	0	0

J. GORDON, C.E.

September, 1863.

REMARKS BY DEPUTY COMMISSIONER.

The design is most chaste and beautiful, and will be as perfectly executed by Mr. Gordon, though not within the period which was first anticipated. The estimate exceeds very much what was first expected. It has been considerably increased by the unexpected cost of ten clock dials, and the bell. These have been underestimated by at least Rs. 1,000, which may be added to the aggregate sum. The bill for customs duties and carriage, viz., bullock train and steamer up-country, has not been included. From letters I have received from Messrs. Grindlay and Co., I am prepared for these charges, amounting to at least Rs. 1,000.

T. W. MERCER.

No. LXI.

THE INDUS TUNNEL.

(2ND ARTICLE.)

Abridged from a Report upon the Indus Passage at Attock, prepared agreeably to the orders of the Government of India. BY LIEUT.-COL. ALARIC ROBERTSON, *Superintending Engineer.*

I WILL now refer to the *modifications* which could be made in the scheme for a Tunnel, by which to reduce the first cost, and which would provide fair, though modified facilities, for the traffic, should the cost of the entire scheme as above submitted be considered too great.

The simplest form to which we could reduce the Tunnel, would be that proposed by the Secretary to the Government of India, (Col. Strachey, R.E.,) viz., to complete the *river* section, either as a single or a double roadway; work the traffic through that, either by our own cattle or machinery, and hoist it up and lower it down Shafts constructed for the purpose. And to this arrangement, much consideration has led me to believe that our operations should be limited for the present, leaving the approaches to be dealt with hereafter.

In the details of this scheme the first point is the *width.* A present saving might be effected by reducing the width of the main tunnel, but not only with regard to present arrangement, but to the future possibility of completing approaches, this I think would be bad economy; as reducing the traffic to a single line, would add much to the delay incidental to the proposed mode of lowering and raising the heavy traffic, and would make this objection permanent, except at great cost, which would be in-

curred by the construction of a second line of tunnel, while the immediate saving would not be large.

The next point is the *Shafts* on both banks. I agree in opinion with Colonel Strachey, that in this modification of the scheme, extraordinary floods should be disregarded. With the pumping engines I propose, *i. e.*, about 30-horse power, the whole tunnel and shafts, if filled, could be cleared under nine days; so that the engines being in a place of safety, the only inconvenience would be the stoppage of the traffic for this time, and with fair warning, temporary precautions might be taken for even preventing the tunnel being filled.

The shafts at present are, one on the left bank, of 10 feet diameter, designed as the pumping shaft in the complete tunnel, and therefore situated on one side of the line, the centre of it being 24 feet from the centre of the line of tunnel. This shaft I would propose to leave exactly as it is, and use it for the purpose originally designed, viz., for pumping and for the gas mains.

On the right bank, the shaft at present is 9 feet diameter, and is situated within the ordinary floods, as shown in the section, and is now raised in a masonry column 24 feet high, which is beyond ordinary floods. This shaft I would purpose also to retain, as an air or ventilating shaft, and for working, while the others which I propose, were being sunk. But small saving would be made by enlarging this shaft, as all the masonry column and brick lining would have to be removed, and we should have to suspend all work below while this was going on.

The *Lift Shafts* I propose to make 28 feet internal diameter, and line them with 1 foot thick of brick masonry, and in these shafts to work two lifts—an ascending and descending one—a single lift might be considered sufficient, but the saving is so small that I recommend the two. The machinery must be the same for one as for two, and in lieu of the second we must have a counterpoise weight, so that the only saving would be the mere cost of the lift frame and a small decrease in the size of the shafts.

The lifts I propose to make 13 × 8 feet interior dimensions, the side frames 6 feet high; this size of lift is sufficient for the accomodation of a 12-pounder field gun, which I think enough. I attach drawings of the lifts and the lift machinery, and also of the timbering of the lift shafts. The lifts will work along guide rails, and there is a set of safety levers, to prevent the descent of the lift in case of the breaking of the rope.

On the rope drum there are two powerful friction bands, (two instead of one, in case of accident to one,) by which the lift will be lowered, and the cattle will only be required in raising.

The machinery, to be worked by six pair of bullocks, has a fast and slow motion. By the former, the amount it will raise will be about 4,400 lbs., or 2 tons, at a speed of the rope of about 54 feet a minute; by the latter, the weight about 13,200 lbs., at a speed of rope of 18 feet a minute.

I propose cattle for the lifts in lieu of steam power, as more economical; the heavy traffic is small, and of course irregular, for days there will not be a cart, and then a large convoy. With steam power, steam would require always to be kept up; with cattle, keeping only one set available for work, we may employ the others on other duty.

On the left bank I propose to place the lift shaft, just on the edge of the Lahore and Peshawur road, and at once accessible from it. The machinery above on the high ground.

On the right bank I place the shaft, just behind the present shaft, and only sufficiently far from it, to avoid injuring it in the excavation of the new shaft. This shaft being within the ordinary floods, must be raised well above them, and be connected with the high ground by a viaduct. The arrangement is all shown in the accompanying plan and section.

The actual length of the river section of the tunnel I make 1,175 feet. On the Attock side the distance to the lift platform is 165 feet; this I make at a grade of 1 in 20, with a 20 feet level platform in front of the lift. On the Khariabad side, the distance to the lift platform is 90 feet, and the level space in front 30 feet, or a total length of tunnel of 1,480 feet.

To take cattle and foot passengers up by the lift, would not only be inconvenient but expensive, I therefore propose a path at a inclination of 1 in 10 for this purpose; the path I would make 14 feet wide, and 12 feet high, so as to allow of the passage of an elephant unloaded. I would divide the path into an 8 feet road for animals, and a 6 feet footway for foot passengers. By this way, all animals would pass; even many of the loaded animals would use it. Carts would be drawn to the edge of the lift by their cattle, the cattle would go down by the path, and find the cart at the bottom; the cattle would again drag the cart to the other lift, and be taken up the path to find the cart ready for removal above.

The cost of the paths would only be Rs. 95,952; and I think their

value would be saved in the working expenses of the lift. By making a large shaft, say 60 feet diameter, a path might be constructed round it, but I think the cost of this originally would be little less than that of the path, while the wear and tear would be considerable. The path once made may be almost said to be permanent. There are also other objections, previously stated, to a large shaft.

With regard to this scheme, there is another point to consider. Might it not be advisable to continue the tunnel on the right bank to the high ground, and there form the lift, and save the viaduct and masonry round the shafts? The original cost would be more, and the current expenses higher in lighting; 600 feet more of tunnel would cost Rs. 46,139, and the cost of masonry and viaduct is about Rs. 17,728. There would be some small saving in the path-way, but of very trifling amount.

In this scheme I would still use gas for lighting; it is the only efficient means. The pumping engines as provided for the full tunnel I would not propose to alter in any way, but the gas apparatus would be much reduced.

Full detailed estimates of original cost and maintenance are attached. The former amounts to Rs. 5,51,042·011, and the latter to Rs. 16,499·9,* this includes cost of cattle for lifts, &c.

We might consider next, the completing the tunnel with much steeper slopes, such as 1 in 6 or 7, and working the traffic through by machinery; using half the way for animals and foot passengers, and half for carriages of all kinds, transported on trucks on a tramway; but I think the plan above detailed is so far preferable to this, that it is scarcely worth considering.

ESTIMATE showing probable cost of MAINTENANCE for complete Tunnel, and for Tunnel under river only, with Lifts and Footway.

This may be divided into PUMPING and LIGHTING.

PUMPING.

The water has to be raised 194 feet; working the engine to 10-horse power, night and day, the results should be 1,633 cubic feet, or 10,206 gallons per hour, or 49192· cubic feet, or 2,44,944 gallons, in the 24 hours; more I think than we are likely to have to dispose of.

The expenditure per horse power of fuel in a Cornish engine, taken at

* Rate per yard run, Rs. 1,117.

a very high rate, is 4lbs. per horse power per hour; $3\frac{1}{2}$ would be a fairer average, but I take a high rate, $24 \times 4 \times 10 = 960$lbs. coal per 24 hours for the engine.

Now the value of wood to coal is as 10 to 4, $\frac{960 \times 10}{4} = 2{,}400$ lbs. wood or $\frac{2400}{80} = 30$ maunds, and at 8 maunds per rupee, (the present road rate in the Attock division,) we have, Rs. 3-12-0 per day, or per annum,

Rupees, ...	1,368·75
Stores and repairs, may be taken according to an average of the London Water Works, at one-fourth the cost of fuel, Rupees,	342·18
Four stokers, and four assistants in the engine room, at Rs. 8 and 12, respectively, Rupees, ...	960·
One European Engineer, at 150 Rupees, ...	1,800·
Annual cost of Pumping, Rupees, ...	4,470·93

LIGHTING FULL TUNNEL.

$\frac{7200}{50} = 144$ lights.

Ventilation; 9 sun burners, 144 lights, workshops, &c., equal to 4 lights, day and night, as for the tunnel.

A fish-tail or bat-wing burner, will consume $1\frac{1}{8}$ cubic feet of gas per hour, at full height; reduced at night to $\frac{1}{2}$ cubic foot, or it may be much less. But assume $\frac{1}{2}$ a foot; and take 12 hours at $\frac{1}{8}$, and 12 hours at $\frac{1}{2}$ $= 13{\cdot}5 + 6 = 19{\cdot}5$ in the 24 hours, for each lamp in tunnel.

$19{\cdot}5 \times 148 = 2886{\cdot}$ cubic feet per 24 hours for lighting tunnel.

Ventilation for 12 hours only, as the natural ventilation will act during the night; and allow each light in the sun burners 1 cubic foot per hour $144 \times 12 \times 1 = 1{,}728$ cubic feet per day, and it will be a full allowance, if we allow for ventilation by artificial means, for 3 months in the year.

Cost of Lighting.—The yield of gas from oil is variously stated in works on the subject. In "Brand's Dictionary of Science," it is given as 100 cubic feet from the gallon of oil; "Ure's Dictionary of Arts," 141; "Knapp's Chemistry Applied to the Arts," 150 to 175. The specific gravity of oil at home being ·92 to ·94, and the weight of a gallon 9·2 lbs. to 9·4 lbs.

I constructed a small apparatus, and tested the oils of the Punjab, and

the rock oil, or Petrolium of Kalabagh. The common "Tara Mera," or wild mustard oil, (the cheapest in the market,) has a specific gravity of ·937, and weighs 9 375 lbs. to the gallon. Petrolium has a specific gravity of ·95, and weighs 9·5 lbs. to the gallon.

The yield of gas from mustard oil was 70 cubic feet to the gallon, from petrolium 80 cubic feet. In a large apparatus the yield would no doubt be much greater, as there is less waste and more economy of working, but I will take these results.

The cost of mustard oil is 6 seers per rupee; of petrolium, in the Attock godown, 3 Rs. per maund, or for 8·632 gallons, or Rs. 0-5-6 per gallon; but as the cost of carriage from Kalabagh to Attock by boat is only 8 annas, and the mere collection cannot be more than 8 annas in addition, 1 Rs. a maund would seem to be a full price; and I suppose the cost of barrels has been included; but I will take it in this estimate at Rs. 3, though it must be remembered that this is three times what it should cost.

$\frac{2886}{80} = 36{\cdot}07$ gallons of petrolium required for lighting for 24 hours.

$\frac{1728}{80} = 21{\cdot}6$ gallons for ventilation.

		RS.
36·07 at 5-6 =	.. .. ..	12·4
21·6 at 5-6 =	.. .. ..	7·42
12·4 × 365 days =	.. .. ..	4,526
7·42 × 90 days =	.. .. ..	667·5

In "Weale's Series," "gas lighting" fuel to produce 2,000 cubic feet of gas is stated as	560
"Ure's Dictionary of Arts,"	416
"Cressy's Encyclopedia of Engineering,"	261

and as Oil gas is produced more rapidly, and at a lower temperature than coal gas we may assume these quantities as excessive; but yet I will take the largest—

Value of wood $\frac{560 \times 10}{4} = 1{,}400$ lbs. wood per 2,000 cubic feet gas.

$\frac{2886 \times 1400}{2000} = 2020$ lbs. $= 24{\cdot}64$ maunds, $=$ Rs. 3·08.

$\frac{1728 \times 1400}{2000} = 1209$ lbs. $= 14{\cdot}75$ maunds, $=$ Rs. 1·84.

Annual Cost *for complete Tunnel*

	RS.
Petrolium for lighting, as above, at	4,526
„ ventilation, at	667·8
Fuel for lighting 3·08 × 365, ...	1,124·20
„ ventilation 1·84 × 90, ...	165·60
Four stokers and four attendants, at Rs. 8 and 12, ...	960·
One European, at Rs. 150, ...	1,800·
Repairs, ...	300
Two lamp cleaners, at Rs 6, ...	144·
Rupees, ...	9,687 60
Cost of Pumping as above, ..	4,470 93
	14,158·53
Contingencies at 5 per cent., ...	707·92
	14,866 45
Add for petty repairs to tunnel shafts, &c., ...	1,000
Total Rupees, ...	15,866 45

If the supply of petrolium were to fail (which is unlikely) and oil be used, the annual cost would be Rs. 23,529.

Broad streets are well lighted at home with lamps at 100 feet intervals. In the tunnel, whitewashed, it may most likely be found that this amount of light is sufficient, which would at once reduce the cost one-half.

For *Tunnel under River only, with Lifts and Footway*, the Annual Cost for Lighting with petrolium, would be Rs. 11,780, and with oil, Rs. 15,261.

EXPENSE OF LIFTS.

6 pair of bullocks to each lift, for full work; and as the lift will never be worked for more than 4 or 5 hours, except on extraordinary occasions, if we allow 2 pairs for reliefs and sickness, it will be enough.

14 pair bullocks, at Rs. 17 a month each, ...	238·
6 breaks-men at lifts, 2 men at platforms, and 2 men below, 2 spare, 12 men, at Rs. 6, ...	72
Per month, ...	310·
Per annum, ...	3,720·
Repairs, oil, ropes, &c., ...	1,000·
Total Rupees, ...	4,720·

		RS.
Lighting and Pumping,	.. ..	11,779·9
Total cost of Maintenance of Tunnel with Lifts, ..	.. ..	16,499·9
Extra cost, if petrolium failed and oil had to be used,	.. ..	3,481 32
Grand Total Rupees,	.. ..	19,981 22

A. ROBERTSON, MAJOR.

MEMO. BY THE LIEUT. GOVERNOR OF THE PUNJAB.

I visited the Tunnel at Attock on the 30th April, and, as the work is one that excites considerable interest, I propose briefly recording what I saw. I asked Lieut. Chalmers, Assistant Field Engineer, who accompanied me, for a memo. showing the progress made, and the present state of the works. His memo. is so full and complete, that I prefer transcribing it for the information of the Supreme Government.

I can add, that the work is being carried on most vigorously—night and day—and that there does not appear to exist in the minds of any, a doubt as to the success of the work. The deepest portion of the channel has been passed, and the rumbling of boulders overhead, carried along by the rapid rush of the current, has been occasionally heard.

Major Robertson, the projector, has gone to England, and will purchase such machinery as is required. Captain Sandilands is supervising the work in his absence, but the hard work of excavating falls on Lieut. Chalmers of the 24th Punjab Infantry, and his gallant Muzbee miners, aided by six European miners. All are indefatigable, and work with the greatest spirit.

The natives of the country are greatly interested in the work, and think far more of it than the Railway works or system of Telegraph lines. Many come from distant places to visit it, especially from beyond the Khyber.

(Signed) R. MONTGOMERY.

Hurreerpore, 6th May, 1861.

Memorandum referred to above.

The first blast for sinking the shafts on this work were fired in March 1860, in presence of the Governor General and Commander-in-Chief, but

as sometime was subsequently taken up in preliminary arrangements, it can hardly be considered to have fairly commenced before the end of April in that year.

A shaft had to be sunk on each side of the river, which is here 1,505 feet 6 inches between its banks. That on the east side is 168, and that on the west side is 93, feet deep, besides 8 feet extra on each side for drainage.

The shaft on the east bank went on steadily at a rate varying from $3\frac{1}{2}$ feet at first, to $7\frac{1}{2}$, 8, and, on one occasion, 11 feet per week, as the men became better acquainted with the work. Until it was within 20 feet of its full depth we met with no difficulties beyond the extreme hardness of the rock, in every foot of which powder had to be used; but, at this point, having got below the bed of the river, the sides of the shaft were subjected to the action of water; masses of rock were detached at times, causing extensive and most dangerous slips, whilst a constant shower of smaller stones wounded, more or less seriously, the men employed. Fortunately, however, no fatal, or even very serious, accident occurred, and the shaft was pushed on without delay to its full depth, although in one week upwards of 20 wounded men were sent into hospital.

It was now considered advisable to line the shaft at once with brick masonry, instead of postponing this operation until the completion of the tunnel, as was at first intended; and, although this caused us some delay, there can be no doubt but that it saved many accidents, and possibly some lives.

From the bottom of the shaft two galleries proceed straight northwards to a distance of 25 feet. They are each 6 feet high and 3 feet wide; and at their further ends are met by the main drift, which crosses the river westwards, and is of the same dimensions.

This drift has, at its furthest point reached, on this date, a distance of 160 feet and is completed to 150 feet, with a railway for the removal of the material excavated; it has a rise of 1 foot in 300 for the purposes of drainage, which at present is very trifling, being only about 7 or 8 cubic feet per hour.

At the level of the Lahore and Peshawur road, a gallery has been driven in to meet the perpendicular shaft; by this, water, and the rock excavated, are now removed, saving a lift of 42 feet to the top of the bank.

The whole amount of work executed on this side, during the past year,

is as follows:—Shaft, 176 feet; double galleries to northward, 50 feet; drift gallery, to cross river, 160 feet; gallery from the Lahore road, 50 feet; being in all, 176 feet of shaft, and 260 feet of gallery, all through solid rock; besides 160 feet of brick lining to the shaft, during the execution of which, the excavation, although not altogether stopped, was materially delayed.

The number of men employed is seven below, and eight above, ground. Those in the gallery work four hours in the twenty-four, and those in the windlass eight. There are three European miners of H. M.'s 94th Regiment, who assist and instruct the natives. The work has gone on without intermission by night or day, since its commencement.

The west shaft, or that on the Peshawur side of the river, is situated close to the river's edge, and much below the summer level. A hollow pier of masonry had therefore to be built up 24 feet, to keep out floods, and this, with a delay of two months during the last rains, from the insufficiency of the means available for keeping down the water, has thrown the progress on this side considerably behind that on the east or Attock bank.

The shaft is excavated to a depth of 93 feet, with 8 feet extra for drainage—102 feet in all—and the gallery has, to-day, reached a distance of 243 feet, of which 235 feet are completed and fitted with a railway. This gallery falls at a rate of 1 foot in 300 towards the Attock side, to which all drainage will eventually be directed. At present a deep drain is cut at one side of the gallery to bring the water back to the well in the shaft.

The principal difficulty on this side has been our very limited means of removing the water, although we have also had to encounter very dangerous slips in the shaft. This is about to be obviated by a horse-power chain pump ordered from Roorkee; and as we are now well past the deepest part of the river, and into a ridge of very solid rock, between which and the east bank the river bed is always dry in the cold season. I think there is reason to hope that our main difficulties are over, and that on the arrival of the Roorkee machinery our means of keeping the works dry will be ample.

Our progress for the last two months, has, on this side, averaged 60 feet per month, and has steadily increased from the commencement. The same number of men are employed here as in the east gallery, and their

hours of work are the same; they have a similar amount of European instruction and assistance, and the works on both sides are under the superintendence of an officer of the corps.

The shaft on this side has also been lined with brick masonry, to prevent accidents, and likewise to diminish the leakage from the river. The water is drawn up by bullocks in relays of two pairs at a time.

It may be considered that the number of hours the men work below ground is small, but it must be remembered that they have excessively severe labor to perform in a very dense and oppressive atmosphere; that they are wet through from the time they descend the shaft until they return to their lines; and finally that they are soldiers, and must be kept in a fit state for active service at any moment. The health of the detachment employed on the work has been most excellent; there are at present only 2 per cent. in hospital, and a part of this number are in with bruises or slight injuries received on the work; and contrary, I believe, to general expectation, the six Europeans employed, although hard worked both by night and day, have enjoyed almost uninterrupted good health; one man was three days in hospital last year, and one has been two days sick this season.

The work has been hitherto singularily free from accident, indeed much more so than I recollect of any similar undertaking at home. With one exception there has been no loss of life or limb. That was a case of a man, who in coming up the east shaft, became suddenly giddy, let go his hold of the rope, fell to the bottom, and was killed on the spot. Since that time an arrangement has been contrived by which a man can at once secure himself to the bucket rope.

The whole work has been performed by a detachment of the 24th Punjab Infantry, under one of their own officers, and I feel assured that such employment must in every point of view be of the greatest utility to the corps, and they are now without doubt, the very best miners in the country, a qualification which of itself may prove of great advantage to them as soldiers; but in addition to this, the constant healthy employment, and habitual exposure to no mean amount of risk and danger, must, besides keeping them out of mischief, preserve both their minds and bodies in the very best state for active service.

JOHN CHALMERS, LIEUT.,
24th Punjab Infantry.

2nd April, 1861.

No. LXII.

RAWUL PINDEE AND MURREE HILL ROAD.

Memo. on Rawul Pindee and Murree Road from Barakow to Murree. By Major H. Rose, *Executive Engineer.*

The road enters the hills at $14\frac{1}{2}$ miles from Rawul Pindee. For 9 miles it passes through low hills and then descends into the valley of the Korung, which it crosses close to Salgram villages; it here enters the higher range, and ascends gradually to Murree. Up to Sunny Bank, which is close to the station, it runs in a north-easterly direction. There are only four short zig-zags at the 23rd mile below Trait, above Shamli, and at the 36th mile. There is a Dâk Bungalow at Barakow, close to the entrance to the hills, and another at Trait, 12 miles distance. There is an experimental Government Garden at Chutter at the 29th mile, another above Shamli, in the 30th mile. The new station of Nund Kote is above the 27th mile; the new road to it turning off at $27\frac{1}{2}$ mile. The Murree Brewery is close to the road at the 33rd mile; and the Lawrence Memorial Asylum on the crest of the hill above; the detachment of Native Infantry is at present located at Sunny Bank.

Width of Road.—As far as the Brewery the road has an average width of 20 feet, exclusive of side drain; from this to Sunny Bank the width has just been increased from 12 to 18 feet; for the rest of the distance it is only 12 feet.

Available for Wheeled Traffic.—The mail cart has been running regularly during the past season as far as the Brewery. Next year it will be able to go up to Sunny Bank. The horses are posted at the 17th, 22nd, 25th, 28th and 30th mile. Carts of all kinds use the road as far as the

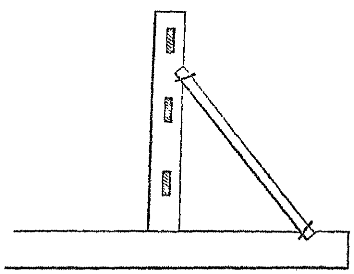
Brewery, and at the end of the season a considerable number went all the way up to Murree.

Gradient of Road.—As far as Salgram the ascents and descents alternate, but beyond that place the gradient of about 1 in 20 is continuous. At a good many places where corners have been cut off, and the road shortened, the gradient has been slightly increased.

Formation of Surface.—Cross sections are given to show the general form of road. In most places it is now higher in the centre than at the sides; when it was first made, and the width was only 12 feet, it sloped inwards. From the experience of last season, when the rains were heavy and wheeled traffic considerable, it is evident that the rise in the centre is much better than having the highest point at the outside, even with a slope of 1 in 15, which it would have been difficult to give. In many places, it was found impossible to keep the surface of the road in tolerable order, but where the road had been made with the rise in the centre, and the earth had settled, it remained comparatively speaking dry and firm.

Bridges.—There are only five bridges of any size, and those are all timber. Plans, &c., of them are forwarded. The first is just at the entrance to the hills; the second and third in the 16th and 17th mile, respectively; the fourth close to the Government Garden at Chutter; and the fifth at Salgram.

Road Drainage.—There is a drain 2 feet wide on the inside of the road. Annexed is a list of drain bridges with their width, &c., &c. There are no catch-water drains: these are required in many places where, owing to the want of them, the ground is constantly slipping; the side drains are kucha. The drain bridges are principally of dry stone masonry abutments, with covering of jungle wood beams; some are of pucka masonry and arched.



Up to the Brewery the outside of the road is protected at most of the dangerous places by railings made of undressed jungle wood; the uprights are about 6 × 4 inches let into sand sills, and with a strut on the outside. At a few places in the 23rd and 26th miles, there are masonry parapet walls, but they do not stand well, and as they decrease the width of the

road by $1\frac{1}{2}$ feet, railings appear preferable; railings are in course of erection from the Brewery to Sunny Bank, where the road is being widened to 18 feet.

STATEMENT OF DRAIN BRIDGES BETWEEN BARAKOW AND MURREE, ON THE RAWUL PINDEE AND MURREE ROAD.

Mile.	Width—Feet.															
	2	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
15	8	..	..	2	..	..	..	..	..	..	..	..	..	..	..	..
16	15	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..
17	13	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..
18	19	4	..	..	..	..	..	..	..	1	..	..	..	..	..	..
19	19	2	..	..	..	..	..	1	..	..	..	..	..	..	..	..
20	17	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
21	23	..	..	1	..	..	..	..	..	..	..	..	..	..	2*	..
22	23	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..
23	18	4	..	1	..	..	..	..	..	..	..	..	..	..	..	..
24	13	..	..	5	7	..	..	..	..	1	1	..	..	..	..	..
25	12	..	3	..	..	..	..	..	..	..	..	..	1	..	..	..
26	17	6	..	2	..	..	..	..	..	..	..	..	1	..	..	..
27	6	7	..	12	..	1	..	..	..	..	..	..	..	..	..	..
28	14	..	..	6	1	..	..	..	1	..	..	1	..	..	..	..
29	15	..	3	6	..	2	..	..	1	..	..	..	..	..	..	..
30	19	..	..	4	..	2	..	..	..	..	..	..	..	..	..	..
31	11	..	1	..	1	..	..	..	..	..	..	..	..	..	..	..
32	7	3	2	..	..	..	..	..	1	..	..	..	..	..	..	..
33	15	2	..	2	..	..	..	1	..	..	..	..	..	..	..	..
34	20	1	1	..	..	..	..	2	..	..	..	..	..	..	..	..
35	25	..	..	..	2	1	..	2	..	..	..	..	..	..	..	..
36	26	..	..	2	2	1	1	..	..	..	..	..	..	..	..	..
37	24	..	3	..	3	..	..	..	..	..	..	..	..	..	..	..
38	22	..	..	..	..	2	..	..	..	..	..	..	..	..	..	1
Total,	401	30	17	43	16	9	1	6	4	2	1	1	2	..	2	1

* Bays.

The following specification for the Salgram Bridge, the largest on the road (see plan) erected by Capt. Glover, R.E., in 1855, may be found useful:—

The *Bridge* to consist of one span 60 feet wide, the abutments to be built up solid, their foundations resting on the rock on each side. The faces of the abutments to be of dressed stone of the largest size procurable, the backing to be of rubble stone, the whole laid in the best mortar. The sides and front of the abutments to have a batter of 1 foot to 6 feet in perpendicular height, and to be 27 feet wide at the level of the top of the beams.

All timber to be dressed, square edged, free from knots or shakes, and of the dimensions given.

The *Trussed Beams* to consist of two chords placed 8 feet apart from inside to inside, and connected by upright ties and diagonal braces, and further strengthened by arch braces. The whole of the timbers where they cross one another to be firmly connected by treenails of hard wood, firmly driven with a little oil, and to be driven till the planks fit close to one another, their heads also to be well wedged.

The *Treenails* to be octagonal, 2¼ inches diameter, and to be driven into holes slightly smaller in diameter.

The *Upper Chord* to consist of four layers of plank, 14 inches by 3 inches, laid two and two together, with a space between, sufficient for the admission of the vertical ties and braces. The upper chord to be joined where necessary by a simple abutting joint; the ends of each plank to be fitted with great precision, and to have a fair bearing, and to be well driven home until they fit close; in case of opening between the joints, wedges of hard wood should be firmly driven in between the ends of the planks. The joints to be broken so that no two joints come together, they are to be further secured by four treenails, two to be driven on each side of the joint.

The *Lower Chord* to consist of four layers of plank, 14 inches by 4 inches, laid together in a similar manner. The joints of the lower chords should be further strengthened by iron straps, 3 inches by ¾-inch, firmly bolted with 1½-inch iron bolts; the space between the chords to be filled in with a solid block of wood wherever a joint occurs. Care should be taken that no two joints come together and the joints should, moreover, be made as far from the centre of the bridge as practicable. The planks of both upper and lower chords should be as long as can be procured.

Upright Ties, 12 inches by 3 inches, to be placed at intervals of 2 feet 9¼ inches from inside to inside, and perpendicularly between the upper and lower chords, the two last ties at each end near the abutment to be placed 2 feet 11½ inches apart. The ties to be connected with the chords by treenails of hard wood.

Diagonal Braces consisting of double planks, each 10 inches by 2½ inches, and placed one on each side of the upright ties, to be added, they will be so laid as to connect the top and bottom of each alternate tie.

The whole of the braces and ties to be firmly connected with the upper and lower chords, and also with one another where they meet, by treenails of hard wood. The treenails to be driven till all the planks fit close, and their heads to be well wedged.

The truss to be further strengthened by *Arch Braces*, 12 inches by 6 inches, one on each side of the vertical ties and braces. The joint of the braces and straining piece to be accurately fitted, and to be further secured against drooping or slipping, by small pins of hard wood driven into their ends. The lower end of the braces to be let into the lower tie. The arch braces to be secured to the vertical ties and braces where they meet by treenails.

The three trusses to be firmly fastened together by horizontal ties, laid 9½ feet apart, above and below both the upper and lower chords, and firmly bolted together with 1-inch iron bolts, with screws and nuts driven into ⅞-inch auger holes. They are to be further strengthened by vertical bracing, consisting of small beams, 6 inches by 5 inches, laid diagonally, and abutting against the upper and lower chords. These braces to be fastened together where they meet by treenails.

The upper chords to be further connected by a *Weather Bracing* laid horizontally, and consisting of timbers 6 inches by 5 inches, diagonally laid across the bridge. These braces to abut against blocks of hard wood, let into the upper chord to a depth of ¾-inch, and fastened to it with 1-inch iron bolts, with nuts and screws.

The *Roadway* to be laid on the upper chords, and to be supported by roadway beams, 10 inches by 6 inches, laid transversely, 3 feet $3\frac{1}{2}$ inches apart; these beams to be placed as close to the upright ties as possible, and not in the bays between them, so as to have the advantage of the strongest part of the upper chord. Each roadway beam to project alternately on each side of the roadway 3 feet 9 inches, so as to afford a support for a diagonal brace for the support of the railing.

Joists, 6 inches by 4 inches, to be laid longitudinally, 16 inches apart from centre to centre: one joist to be laid over the open space between the upper chords of each beam, and to be firmly fastened by an iron bolt with screws and nuts, 1 inch diameter, to a piece of hard wood, 4 inches by 9 inches, laid across the under side of the upper chord of the trussed beam, so as to connect the roadway firmly with the trussed beams.

The roadway to be 24 feet wide inside the railings, and to consist of planking 3 inches in thickness laid diagonally across the bridge, and abutting end to end at the centre, and firmly spiked down to the joists.

The *Railing* is made 3 feet high from the flooring planks to the top of the handrail. To consist of a handrail 8 inches by 6 inches, laid horizontally, supported and also tied to the bridge by double uprights placed over every alternate roadway beam; these uprights are cut out and fixed round the joists with an iron bolt and nut, and are again cut out at their upper ends to allow them to pass round the handrail, when they are again bolted, diagonal pieces are placed between these uprights and mortised into them, to prevent them falling out in case of shrinking of the wood. In order to give stability to the railing, the roadway beams over which the uprights are fixed are prolonged, and a slanting brace is abutted against the roadway beam at one end, where it is fixed by an iron strut, and against the upright at the other, where it is fixed by an iron bolt and nut.

The *Wall Plates* are formed by longitudinal beams, 8 inches by 12 inches, laid on the flat longitudinally with the bridge on the abutments, 3 feet apart, and on these other beams of the same dimensions are laid transversely with the bridge, along the face of the abutment on which the three trussed beams are laid: these beams should run transversely across the whole abutment.

As the lower chord, from (the nature of the strains upon it, which are tensile, thereby causing a tendency to open in the joints by which means the whole section of the timber does not came into play as in the upper chords) is the weakest point in the construction, it should be as far as possible relieved by giving the ends firm abutting points, which in this case can be very easily effected on account of the very solid abutments, by driving in wedges of hard wood in rear of the ends of the trussed beams, thus transferring their strains to the abutments. This can be effected by placing upright beams, 8 inches by 12 inches, at every 3 feet apart, and about 6 feet in length, at the ends of the lower chords; their centres being in the same level as the chords, and against these another beam, 14 inches by 8 inches, is laid horizontally across the abutments, and about 8 inches distant from the ends of the lower chords; in this interval strong wedges of hard wood should be firmly driven, thus giving a fair bearing to the chords, whose strains will be thus transferred to the abutments, and be distributed over them by means of the upright beams.

No. LXIII.

FLOOD DISCHARGE OF RIVERS.

Note on the Flood Discharge of Rivers and Streams with reference to determining the Size of Bridges from Drainage Areas. By Lieut.-Col. C. H. Dickens, R.A.

Let M = the number of square miles of drainage area of any river or water-course, no matter how small.

Let D = its discharge at highest flood, in cubic feet per second.

$$\text{Then } D = 825\ M^{\frac{3}{4}}.$$

Or in logarithms—

$$\text{Log } D = \log 825 + \tfrac{3}{4} \log M.$$

This formula is, of course, only applicable to cases within a certain average of annual rain-fall—say of 36 inches in the year. It may, however, be considered to hold approximately to all cases from 24 to 50 inches of average annual rain-fall; as the heaviest fall of rain varies less in proportion than the total annual rain-fall.

The manner in which this formula was arrived at is as follows:—

Let it be granted, first, that over a small area, say of 8 acres, the rain-fall may be as much as 4 inches in an hour. I have myself measured 3·98 in 68 minutes; and I think Lieut. Greathed, R.E., in his Report on the Drainage of Delhi, gives $4\frac{1}{2}$ inches in the hour, as an actual case. In the case of these very heavy falls of short duration, the whole will drain off at once if the ground be previously wet.

Next, take Sir P. Cautley's rule of $\frac{1}{2}$ an inch in the hour for small rivers, and assume it exactly applicable to cases of 50 square miles of drainage area.

Then, we have the well-known case of the Damoodah; drainage area, 7,000 square miles, and flood discharge equal to $\frac{1}{8}$-inch per hour of rain-fall.

Lastly, take the Soane; 27,000 square miles of drainage area, and a flood discharge in extreme cases equal to $\frac{1}{10}$-inch per hour over the whole area.

Arrange these in a table, and add fourth root of the drainage area, and the product of this into the rain-fall drainage, thus—

Square miles of area.	Rain-fall drained off in inches.	Fourth root of the area.	Product of the two last
$\frac{1}{80}$	4	$\frac{1}{3}$	1·33
50	$\frac{1}{2}$	$2\frac{1}{2}$	1·25
7,000	$\frac{1}{8}$	9	1·13
27,000	$\frac{1}{10}$	13	1·30

Thus it appears that the rain-fall drained off per hour is inversely as the fourth root of the drainage area—that is in a rough way; and so we obtain the formula $\frac{5}{4\,M^{\frac{1}{4}}}$ to give us the rain-fall per hour in inches which a certain drainage area will discharge in the heaviest floods.

To convert this into cubic feet per second—

$$\frac{5}{4\,M^{\frac{1}{4}}} \times \frac{M \times 5280 \times 5280}{12 \times 60 \times 60} = 806\ M^{\frac{3}{4}},\ \text{nearly.}$$

Instead of this I take as above, $D = 825\ M^{\frac{3}{4}}$, so as to give a little margin on the safe side.

Remembering all the differences of soil, declivity of drainage basin, and rain-fall, it is evident that such a formula cannot be anything better than a rough approximation. But still I think it will be found safer in most cases than the mere determination by reputed flood levels, or by flood marks in jungly tracts. At all events it affords a good method of testing the results arrived at by the former method, and a means therefore of detecting errors which otherwise might have escaped knowledge.

To make use of this formula it is necessary, first, to have the usual data of sections, transverse and longitudinal, of the river's bed. Then determine by a few trials the flood level which would give the discharge required

by the formula. This may be compared with the reputed flood level. If they differ materially, the latter should be again investigated. After this it will be safe to adopt whichever determination gives the highest flood level.

For small drains, it will be quite safe to fix a velocity such as the soil will bear, and allow waterway enough to discharge the heaviest flood as determined by the formula from the drainage area.

The following table, computed on assumed velocities, and assumed proportions between depth and width of streams, shows, in a general way, the results of this formula in determining the size of bridge necessary for a given drainage area.

Drainage area.	Discharge, cubic feet per second.	Assumed velocity, feet per second.	Square feet of Water-way.	Bridge for common cases.		
				No. of spans.	Span in feet.	Height of piers or abutments.
1 acre,	6½	5	1½	1	1½	1
2 "	11	5	2¼	1	2	1⅛
3 "	15	5	3	1	2	1½
5 "	22	5	4½	1	3	1½
8 "	31	5	6	1	3	2
16 "	52	5	10½	1	4	2½
40 = $\frac{1}{16}$ sqr. M.	103	6	18	1	6	3
⅛ square mile,	173	6	29	1	7	4
¼ "	292	6	49	1	10	5
½ "	490	6	81	1	12	7
1 "	825	6	137	2	12	6
2 "	1,388	7	200	3	12	6
3 "	1,881	7	270	3	14	7
5 "	2,760	7	400	3	16	8
7 "	3,550	7	507	3	18	9
10 "	4,640	7	663	3	20	11
20 "	7,804	8	975	5	20	10
30 "	10,577	8	1,322	5	24	11
50 "	15,605	9	1,734	5	30	11½
100 "	26,094	9	2,899	5	40	14¼
200 "	43,884	10	4,388	7	40	15½
300 "	59,481	10	5,948	9	40	16¼
500 "	87,255	10	8,725	9	50	19
1,000 "	146,737	10	14,673	15	50	19
2,000 "	246,780	11	22,434	15	60	24
3,000 "	334,487	11	30,408	20	60	25
5,000 "	490,636	12	40,886	20	75	27
10,000 "	825,000	12	68,750	30	75	30
20,000 "	1,387,746	13	106,749	40	75	35
30,000 "	1,870,962	13	143,920	45	80	40
50,000 "	2,695,690	14	190,256	50	90	42
100,000 "	4,639,274	15	309,285	60	100	50

These figures will I think be found useful in testing in a rough way the soundness of projects.

But if any of the correspondents of the *Roorkee Professional Papers* would take the trouble to send comparisons of the application of the above formula with any *well ascertained* cases of extreme floods, giving the area of sections, fall per mile, drainage area, and rain-fall of the district, we may be able not only to ascertain within what limits to rely on this formula, but perhaps to substitute a better, and to deduce rules as to the change of co-efficient for different rain-falls. In Lower Bengal, perhaps 1,000 might be written for 825. But for Mahabuleshwur or Cherrapoonjee, some much larger co-efficient would be necessary.

C. H. DICKENS.

27th February, 1865.

No. LXIV.

BRICK-MAKING IN INDIA.

Although the practical Engineer can lay his hands upon several excellent Treatises on Brick-making, as pursued in England and other places, there are not very many which tide him entirely over the minor difficulties he is likely to encounter when starting a brick field in out of the way parts of India, where for ages, and even at the present day, simple processes are found to answer best. We are far from sanguine that the following description will prove equally useful in all localities, because such extreme differences in both soil and climate are met with, as to render it impossible to adhere to a form of rules in every case with advantage; or it may happen that a better class of brick is wanted than our mode of procedure is calculated to furnish; still since the leading operations are universally the same, it is fair to presume from having experienced a certain degree of success in one instance, that our suggestions will be of some service to Indian Engineers and Contractors.

Where cheapness is an object and the work is not of special importance, Engineers have usually been contented with the ordinary bricks of the country, only turning brick-makers themselves if apprehensive of the supply falling short towards the close of the season, which to their great annoyance and discomfiture will sometimes occur. The quality of this common article depends upon whether the soil of a district is rich or poor in clay, more than upon the amount of care bestowed upon the manufacture of the bricks, and the difference is often considerable; but it will be conceded after glancing over the following account of the way they are made, "passim," that it is needless to look in this direction for really sound or durable bricks. Natives do no more than excavate a few

cubic yards of surface mould from the nearest piece of waste land, and after wetting and turning it over for a few minutes with their hoes, transfer the mud, pebbles, grass, roots, and all, lump by lump at a time, to a double wooden mould, pat it in, strike off with their hands superfluous clay, then raise the mould, leaving two parallellopipeds of semi-fluid mud adhering to the ground; each moulder completing a daily task of about 2,000. These soon dry in the sun, and are ready on the following day to turn over, and in a few days to be burned, either in rude kilns or clamps, according to local custom. Any that survive cartage to site unbroken, owe their preservation to a sloppy way of moulding compensating for deficient tempering, and to the large modicum of sand they contain which reduces shrinkage. They are uncouth in shape, not uniform in size or thickness, and should never be tolerated if it is possible to procure Bench-made bricks.

Bench bricks require a certain preliminary outlay of capital, but are neither difficult nor expensive to manufacture in India, where several months of dry weather can be calculated on, and there is no frost. As is the case with every innovation on the customs of Orientals, a person would find a good deal of friction at first starting, but the people employed should in six weeks' time give no trouble. The first step to be taken is to select the best earth in the neighbourhood, near water, and as free from stones or grit as possible; then to collect the requisite labor, tools, and plant; and erect kilns and sheds. It is of the three latter items we desire to speak.

The pattern of Mould recommended is shown in Figs. 1 and 2, and can be easily put together by an ordinary blacksmith. It is drawn to a scale of 4 inches = 3 feet; interior dimensions being, length, 9 inches; breadth, $4\frac{1}{4}$ inches; and depth, 3 inches. The sides are formed of $\frac{1}{2}$-inch board, lined with $\frac{1}{16}$-inch sheet iron secured by rivets, while the ends are formed wholly of $\frac{1}{4}$-inch iron-plate, rivetted as before. Thin strips of $\frac{1}{16}$-inch sheet iron are screwed down over the edges of the side boards, on both the upper and the under sides of the mould, to save the wood from abrasion, and the whole is neatly finished off by filing. The Stock Board is of wood 2 inches thick, and for $\frac{1}{2}$-inch in depth is shaped to fit the mould accurately but easily. The surface is protected by a thin plate of $\frac{1}{16}$-inch iron, $9 \times 4\frac{1}{4}$ inches, screwed down. The raw brick turned out is therefore $9 \times 4\frac{1}{4} \times 2\frac{1}{2}$ inches; or when burnt, say $8\frac{3}{4} \times 4\frac{1}{4} \times 2\frac{1}{2}$

inches, the length exceeding twice the breadth by the thickness of a mortar joint—which ensures good bond. These moulds are found to last a long time, and are not too weighty to handle. For an intended out-turn of 15,000 a-day, 20 moulds ought to be made up. The Moulding Bench is depicted at one end of the shed in Fig. 5. It consists of a board about 4 feet long and $2\frac{3}{4}$ feet wide, by $1\frac{1}{2}$ inches thick, supported at each end upon pillars of brick in clay, the tops of which are levelled off so as to give an even surface 6 feet long.

The *Page* is also of brick in clay with a piece of wood, let in at the top for the pallet boards to rest upon, $4\frac{1}{2}$ feet long. Upon the bench are placed the stock board, a trough for water, and at the right hand side, the Sand Bin. Books prescribe wooden supports, but the masonry ones do equally well, and are more expeditiously and cheaply constructed in India. The Shed in the sketch is supposed to be large enough to accommodate one moulder, and has hacks for two days moulding, at 1,500 per day. It is 15 feet wide and 90 feet long, and the height of the centre poles is 11 feet, of the eaves 4 feet. Each of the hacks is 70 feet long, and 6 feet wide, and a passage is left down the middle of 3 feet. It is true economy to provide at the beginning a sufficient number of sheds, which may be either thatched or tiled as opportunity permits. The better the clay the more obligatory to allow the newly moulded bricks to remain under cover for the first day. They are generally hard enough to lift by the second, if the air is moderately dry. It is possible, should the clay contain much sand, to conduct the drying in the sun without great risk, but if it is at all strong, nearly every brick will be broken from the violent contraction which takes place. This will also befall them if hot winds are let drive through the sheds.

Before going on to enumerate the rest of the Plant it is desirable to obtain, we have a few words to say regarding the provision of sand, and the treatment of the clay prior to being moulded.

As the moulds must be plied with sand, the finest sort should be collected, and cleared of small stones by sifting through wire gauze sieves. Coarse sand imparts a rough appearance to the brick, and clogs the mould.

The *Sieves* may be shallow wooden boxes with gauze at the bottom, about 18 inches square, and are better suited to the work, as also more lasting than those made of rattan. The state of the sand bins ought

to be looked to from time to time. If not watched the people use any gravel that comes to hand.

In England, where frost tries building materials to the utmost, and the walls of houses are thinner and loftier, as a rule, than they are in India, great pains are taken with the preparation of brick earth, which is dug and weathered for many months before being finally tempered for the moulder. Here, however, in the absence of frost we can dispense with a good deal of this weathering, so that if the clay is excavated during the monsoon, and moulded in the dry season, it is perhaps sufficient.

There is usually a higher per centage of sand in our clays than enters into the composition of marls and loams at home. Dobson sets down 50 per cent. as representing the amount of silica in brick earth, but we are probably not far wrong in asserting, that as much as 70 per cent. will be discovered in fair specimens of Indian brick earth. Its presence to such an extent makes the bricks friable and weak, except lime or alkalies accompany it to act as fluxes, which they do in some places.

The writer having a poor clay to deal with, containing mere traces of those adjuncts, added $2\frac{1}{2}$ per cent. of slaked lime; but the result did not compensate for the expense involved; so the addition was discontinued. A higher temperature in burning, and double the allowance of lime, might have gained the object, but the composition was too caustic for even a laborer's horny hands to manipulate.

In localities where cotton soil prevails, a far more dangerous enemy than sand is met with, which is so minutely interspersed with the clay, as to defy extraction by picking—we allude to nodular limestone. A small fragment, no bigger than a pea, involves such a stream of carbonic acid gas, when heated as to tear open any brick it may lie in. The only expedient is to crush the earth between iron rollers, and thus powder the limestone; for, pulverized, it is not merely comparatively harmless, but acts as a flux to bind the particles of sand together. It is understood that Messrs. Clayton and Shuttleworth furnish a one horse rolling mill for this purpose, at a cost of £35, which a brick-field so situated ought undoubtedly to be provided with, as it is impossible to extemporize an efficient substitute; indeed in all brick-fields its use would be attended with advantage.

The clay has now to be tempered, and upon this operation being thoroughly performed, the soundness of the brick mainly depends. Where

labor is abundant and cheap, men can tread it out with their feet, but if the out-turn is to be considerable, we cannot too strongly advocate the employment of a *Pug-mill*—it will repay itself in the long run.

Fig. 6, is a drawing of one the writer recently had made up under his own eyes, by very ordinary artificers, on a scale of 6 feet to an inch. It is of the London pattern, discharges at the bottom, instead of at the side, and has considerably exceeded anticipation in the quantity of clay it is capable of pugging if mounted as in Figs. 3 and 4. The tub is of wood, $3\frac{1}{2}$ feet wide at top, diminishing to $2\frac{1}{2}$ feet at bottom, (interior measurement,) while it stands $5\frac{1}{2}$ feet high. The staves are about 5 inches wide at top, and 2 inches thick throughout. There are six iron hoops on the tub, 2 inches broad and $\frac{1}{2}$-inch thick. The spindle is of 3-inch square iron, and should be about $7\frac{1}{2}$ feet long; at the lower extremity a cup is formed for the pivot upon which the spindle revolves, and at the upper end, a collar is shrunk on and welded, to prevent it from rising through the bearings. The pivot is of brass, terminating in an iron bolt and nut, to secure it to the transoms; and the bearings are likewise of brass. They are held in their place by a cross head, with three arms, of not less sectional area than 2×2 inches. This cross head is in two pieces, and was found by far the most troublesome part of the machine to make. Before commencing to forge it an exact model should be got ready in wood to guide the workman. Each arm is fastened to the tub by a flange, 2 inches wide, and $\frac{3}{4}$ to $\frac{1}{2}$-inch thick, carrying a couple of bolts and nuts, and should have a piece of stout sheet iron 3 inches wide by $\frac{1}{4}$-inch thick as a washer inside. The tub is set upon two timber transoms and steadied by iron clamps and stays which it is needless to waste space in describing. The stairs ought to be carried down some 3 inches below the level of the top of the transoms, to assist in keeping the tub rigid. The entire machine must be well tarred. As regards the knives, they are seven in number, and 4 inches wide except the lowest, which has no teeth, and is 6 inches wide. The teeth are for the purpose of breaking up clods, and require to be set in a particular manner, as shown in Fig. 7. They may be either screwed or rivetted to the knives. No. 7 blade is inclined at an angle of 55° to the horizon, and all the rest at 45°, affording a strong propelling force downwards, which, slightly opposed, owing to the conical shape of the tub, is partly converted into a kneading action, most valuable in tempering the clay.

The Pug-mill completed, it must be properly set to obtain the maximum effect. A mode which answers admirably, is shown in plan and sectional elevation, in Figs. 3 and 4, to a scale of 15 feet to an inch, where it is placed over a masonry well 3 feet in diameter and 5 feet deep. The transoms are built into the masonry, which is carried up 2 feet high on the tub. Access is gained to the well through openings at the opposite sides, about 3 feet wide and covered with rather flat arches. This arrangement allows the people who fill the machine to walk all round. From the well the clay which falls through, is conveyed away along an excavated passage, and under the bullock walk, by means of bridges, to a 1 in 5 ramp, direct to the surface. This passage and the bridges need be no wider than 4 feet, but any thing less will give too little room, while their construction completely obviates the inconvenience of even stopping the cattle except for rest. Pug-mills are often driven by a single lever, but we decidedly recommend the employment of two as in the drawing, otherwise the iron tripod is sure to be shaken loose. They are each 14 feet long and slightly drooping.

A mill, such as we have sketched, will temper enough clay per diem to keep fourteen or fifteen moulders going, only to do so it must be continuously and cautiously fed. Earth for one day's consumption should be deposited in a heap near it the day before, and be thoroughly watered, and turned over once with hoes or shovels; on no account must it be cast into the tub dry and then wetted, or the knives will assuredly be bent or broken. Of the four quadrantal openings at the bottom two are permanently closed, the others deliver the clay in a very plastic state ready for the moulder. A man in practise will turn out 1,000 a-day with ease, and is capable of making half as many again without distressing himself. He is allowed two men and two boys to assist him, and should be paid at so much per thousand, and not by the day. He is required to keep the hacks clean and level, and to see that the raw bricks are carefully laid in rows upon their sides, because a great deal depends upon judicious handling at this stage. They harden rapidly in this country, and may be lifted off the floors and stacked on the third day, but are let remain exposed to the sun and wind for a week or more before being placed in clamps or kilns.

The former way of burning has its advantages, since the clamps demand no attention after setting and firing till cool, but when time has to be saved, and there is a heavy call for bricks, it is well worth while using

kilns. A large clamp takes weeks to become cold, and unless the bricks are perfectly dry when put in, they are found risen in all directions when the clamp is opened. Kilns on the other hand render it a matter of indifference whether they are wet or dry, since the heat can be regulated so as to drive off the water in steam before the actual burning begins, and the draught which circulates through the flues on the fires being raked out quickly cools the mass down.

A simple kind of kiln is given in the accompanying isometrical drawing, (Fig. 8,) to a scale of 15 feet to an inch. Its length is 41 feet. and width 16 feet, interiorly, and it is 12 feet high. The side and end walls are 4 feet thick at the base, and $2\frac{1}{2}$ feet at top, with a batter on the outside. They are strengthened by buttresses at the four corners of any convenient shape, and by one or more at the sides; but it is necessary to remark that for clearness two corners are shown plain in the drawing, and one of the stair-cases has been suppressed. The side walls are respectively pierced by ten flues, 15 inches wide and $2\frac{1}{2}$ feet high, to the crown of the arches; the end walls have each a doorway, 4 feet wide, flanked by stair-cases by which to reach the top. These doorways are bricked up while the kiln is burning. The masonry may be brick in clay throughout, and only the outer courses need have been burnt, the rest may be sun-dried brick. In fact the rubbish of the yard should be utilized in building them.

Sufficient breadth is allowed between the flues, for laying these bricks end to end, with the space of half a brick to spare, for it was ascertained that having the flues wider and loftier inside than the apertures in the walls, conduced to the more perfect combustion of the wood. When the flues are vaulted over, the piling of the raw bricks on their thin sides is continued solidly to the top, but a few passages 4 inches square are left to augment the draught, and lead off smoke (two or three to each flue suffice.) The last course had better be ground bricks, as it is not possible to burn it through, and on no account ought earth to be heaped on by way of keeping in the heat, till it is time to bank the fires. Steam is given off to the very end of the burning, and must have free vent. After three days and two nights stacking, the flue holes may be closed, and the fires permitted to die out. In this climate, when the rays of the sun are nearly as hot as the contents of the kiln, they can be opened again next day, or that following, to rake out the embers, and admit the air, which

cools the bricks down in about five days time; as a rule, however, the process of annealing should be slow.

Two kilns of the size we have indicated, if half a kiln or fire flues are lit at a time, will yield an uninterrupted supply of 10,000 a-day.

Gauged bricks for arches and pillar bricks, are just as easily made on the bench as common bricks. For the latter sort, it is advisable to divide the circles into five sectors, instead of into quadrants. The mould has radii of $\frac{1}{2}$-inch sheet iron, rivetted to a circular segment, composed of wood lined with $\frac{1}{16}$-inch plate as before, the extremities of which form laps for the hands to grasp.

The depth of the mould is 3 inches, and the stock board is shaped to fit as already described, so that the bricks are turned out $2\frac{1}{2}$-inches thick. The pallet boards should be sectors, and a couple of inches larger every way than the pillar bricks. These last are laid on the drying hacks upon their radial and not upon the flat side, which is the only precaution to be noted.

LXV.

THE SUTLEJ CANAL.

Project for an Irrigation Canal from the River Sutlej; abridged from a Report drawn up under orders of the Government of India. BY CAPT. JAMES CROFTON, R.E.

THE irrigation of the parched tract of country bounded by the Jumna and the Sutlej to the east and west, the Chittung to the south, and the line of the Himalaya to the north, has long been a desideratum, and has been the subject of several able and valuable reports, containing suggestions and projects for its improvement by Col. Baker, Capt. Cunningham, and others; all of which, however, have hitherto remained in abeyance.

Before adverting to the projects for irrigation, it may be as well to describe briefly the features of the country. The watershed line between the Jumna and Sutlej rivers, or as it may be called, the watershed of Hindoostan, runs close to the valley of the former, commencing from a spur of the low hills about 16 miles to the westward of the point where the Jumna debouches into the plains; thence it runs along the high edge of the valley of the Sombe, (a mountain torrent discharging itself into the Jumna a short distance below the permanent head of the Western Jumna Canal,) continuing along, or close to, the edge of the Jumna valley, to some distance below the town of Kurnaul.

The source of the Sursootee is situated to the west of, and close to, the northern limit of this watershed; whence it takes a southerly direction, and is joined by the Chittung below the town of Bilaspore, about 16 miles from its source; thence onwards for another 16 miles the stream seems to be called indifferently by either name, till near the town of Ladwa a separation takes place, the channel to the westward retaining the name of

Sursootee, that to the southward the Chittung, which after its junction with a small drainage channel from the eastward, called the Rakshee, takes a south-westerly direction through the districts of Jheend, Hissar, and Beekaneer, till it joins the Cuggur about 22 miles below Bhutneer. This river then, or rather its valley, may be considered as the actual boundary to the eastward and south, of the tract of country with which we have to do. From Dhatrut in the State of Jheend, to Bahaderah in the Beekaneer territory, the centre of its course is occupied by the Hansee branch of the Western Jumna Canal.

Between the Chittung and the Sutlej, numerous drainage channels intersect the country, running for the most part in a south-westerly direction, some of which must evidently, from their size, have been rivers carrying large volumes of water in bygone ages, though now dry, except during periods of heavy rain. How and when the supply of water was discontinued have long been, and are still, disputed questions, the constant process of degradation of matter from the up-lands near their sources being sufficient, in the opinion of some, to account for the phenomenon, while others considered that the bunding across of the channels for the purposes of irrigation, so extensively practised on the Cuggur and other streams, was the main cause; others again have considered the effect due to the joint operation of both causes and are probably nearer the truth. Whatever the cause of the desiccation may have been, there is now a perennial stream in very few of these channels. The Cuggur and Markundah, the sources of which lie in the valleys of the low hills forming the southern face of the Himalaya, do indeed carry a small supply into the plains all the year round, but this in the case of the Cuggur does not extend ordinarily after the month of April, further down than Chut, about 15 miles from the foot of the hills: while in the Markundah and Sursootee it is still less, and more uncertain. To the west of the Cuggur the channels are dry except during rain.

The Jumna and the Sutlej are the only streams connected with this tract of country, deriving their supply from the snows of the Himalayas, and which is therefore uninterrupted all the year round.

It seems unnecessary here to give a detailed description of the country with reference to its present state of cultivation and its capabilities if only water could be supplied to it, the able authors of the reports above alluded to, as well as many others, having given very full and com-

prehensive information regarding it; suffice it to say that from the line of the Grand Trunk road downwards, there are few spots where irrigation is not urgently required; the need increasing as we proceed southward, where rain is scanty in quantity and of comparatively rare occurrence. Northward of the above indicated line, the influence of the proximity of the hills is felt in the regular and copious supply of rain, sufficient in ordinary years for all the purposes of a luxuriant cultivation.

From the above description it will be seen that there are three sources from which a supply of water for irrigation can be drawn.

1st.—From the Sutlej, which would be constant all the year round, though very limited considering the extent of country to be benefited.

2nd.—From the Sutlej or Jumna, or both, for the autumn crop, which would be constant only for six months in the year, say from April to September, the snow fed rivers usually commencing to rise in March and not materially decreasing till October.

3rd.—From the floods of the rainy season in the channels of the drainage lines between the Jumna and Sutlej, which, however, are very uncertain in their periods of occurrence and variable in quantity.

Projects for the delivery of a supply from each of the sources I have enumerated have been from time to time submitted by various Officers, of which those by Col. Baker and Capt. Dyas, were the most complete, and afforded valuable data for the present project The object of all these projects was restricted to the benefit of British territory exclusively, and their execution was deferred from want of funds, but in 1863, the Puttiala Raja, having requested that the subject might be reconsidered with the view of supplying irrigation to his own territory, and having offered to defray the expenses of the Survey by British Officers, I was appointed to this duty by the Punjab Government.

Colonel Baker's levels having shown, as he observes in his report, that there was little inducement to follow the line of the old Mahommedan Canal,* and the objections to fixing a head for a permanent Canal anywhere below Roopur, being, as he clearly demonstrated, insurmountable; the only other proposal to be re-examined was that of Captain Dyas, who projected a line from the Sutlej about two miles above Roopur to run in a southerly direction, until the edge of the high (or *bangur*) land was

* Known as Mirza Koondee's, and running from Roopur to Sirhind.

reached near the town of Chumkour, whence it could be carried along close to the foot of the high bank until the level of bed would admit of turning into the high land with a moderate depth of excavation, his levels on the high land having shown that the depth of excavation for a channel on that line would be excessive; with a longitudinal slope of bed of 1 in 7000 only "the depth of digging 30 miles from the head would be 22½ feet," and in one place "at the 11th mile as much as 58½ feet." Our subsequent levels show that the depth of a channel with the same slope of bed drawing its supply from this head would be at least 31½ feet at the Grand Trunk road near Barah, even if carried along the most direct line, which of course would be considerably greater were the line lengthened so as to sweep round by the edge of the high bank bounding the Khadir of the Sutlej. The object to be attained is in fact altered; any Canal from the Sutlej, intended, as in the present project, to irrigate the Puttiala territory must, it is evident, run considerably more to the eastward at its entrance into the high land, and as the direction of the drainage lines in that neighbourhood and the levels of the cross section along the foot of the hills, showed a steady rise in the surface of the country from west to east, it was manifestly necessary to carry the line across the Khadir on a higher level, and therefore to seek a head higher up on the river.

For the better elucidation of the details of the present project, it may be as well to describe briefly the physical features of this portion of the valley of the Sutlej. The accompanying map will assist in rendering the description intelligible. The Sutlej may be said to enter the plains close to the town of Roopur, whence its course for a long distance lies due east; above this its course is northerly, and a few miles below the town of Belaspoor, it forms a loop running north-west and south-east, about 40 miles in total length, while the width across the neck is not more than 6 or 7 miles; a ridge of hills, the highest point of which is 3,905 feet above sea level (by the Great Trigonometrical Survey) divides the two sides of the loop. On the north-east side the river runs in a rocky channel, but a little in advance of the point of the loop, enters a valley which continues down to Roopur, varying in width from 2 to 4 miles, the bed in boulders, decreasing in size as we proceed downwards as far as the Suraee Ghât, below which sand and shingle are largely intermixed, until stones are lost sight of in

the sand, a short distance below Roopur. The river runs in one channel to Nungal Ghât a short distance below the point of the loop ; immediately in advance of this, it divides into two main branches, one taking to the left edge of the valley skirting the low hills, until it rejoins the other at the Suraee Ghât, opposite the fort of Boonga ; the larger branch to the westward, is broken up into several shifting channels which unite at the Thanna Ghât, opposite Nundpoor Makhowal, a noted place of Hindoo pilgrimage on the left bank of the river ; below this it again separates, till at the Suraee Ghât, all the streams unite and pass onward past Roopur in one channel. The strip of land which divides the two branches is never flooded except in extraordinary freshes, and then only partially, as may be inferred from the number of villages scattered here and there over its surface. On the eastern side low hills skirt the valley, leaving generally a narrow strip of low sandy land reaching to the bank of the river; here and there however high spurs, as at Keerutpoor and Roopur, extend out to the edge of the running stream, that on which Keerutpoor is situated being not less than 200 feet in height; between Nundpoor Makhowal and Nungal Ghât, the stream washes the foot of a high table land.

From Nungal Ghât to Roopur, the valley is intersected by numerous torrents conveying the drainage from the neighbouring hills into the Sutlej; of these, the largest and most formidable are the Sursa, the Lohund, and that close to Nundpoor Makhowal; the Sursa drains the outer range of hills from the neighbourhood of Pinjor, its catchment basin has a more extended area than the Solanee, and its bed below its exit from the low hills is in pure sand; the Lohund drains the range of hills in the neighbourhood of Hindour, discharging itself into the eastern branch of the Sutlej close to the town of Keerutpoor; its floods bring down quantities of boulders, some of very large dimensions, but from the rapid declivity of its bed little sand is deposited.

Southward of the Roopur spur and between it and the high land, the Khadir is intersected by four nullas which carry off drainage from the southern face of the low hills, all in sandy beds and on steep slopes ; the edge of the bangur here runs nearly east and west, except a triangular promontory about 3 miles in length, north to the village of Sulowra ; between this point and Roopur, three of the torrents pass, the centre one, called in the Revenue Survey map, the Soogh, carrying the largest

and most rapid stream. The Seeswan (so called from a town of that name situated on the outer range of hills, formerly a place of some note) runs a longer course and drains a larger area than any of the other three; its course for the most part lies in the high bangur land, from which it makes its exit close to the village of Balsinda, just where it was crossed by Mirza Koondee's Canal; a short distance above this, its channel, ordinarily not less than 250 feet in width, is suddenly contracted, in passing through a stream of kunkury earth for a length of a mile to 120 feet—at one place not above 100 feet. The banks of all these torrents to the westward of the old Mahommedan Canal are lined with sand ridges, mountains of sand I might say, showing very clearly the diminution of the slopes of their beds in that locality, and the velocity with which their flood waters must descend from the hilly country; above this line there is comparatively little sand visible except in the actual beds. All these channels from Keerutpoor downwards, are dry or nearly so, except during rain.

A reference to the map will show that the Seesooan torrent is the last of those draining directly to the west into the Sutlej. From its left bank the direction of the country drainage is nearly to the south-west, at right angles to its course, from the town of Khurr nearly to Chamkour on the high bank of the Sutlej. This converges to a point above Sirhind whence the floods pass off in the bed of the nullah passing close to that town: the Khurr nullah, which at the point where my levels crossed it, is about 400 feet wide and 5 feet deep, loses its defined section altogether 4 miles lower down close to the fort of Kulour, below which the floods find their way through some low ground to an extensive swamp in the vicinity of Railee, a village three miles north-west of Sirhind, whence they pass on to the Sirhind nullah meeting it just above the old Mahommedan bridge. To reach the watershed to the eastward of the Sirhind nullah therefore, this drainage must be crossed.

The course of any line for a Canal from above Roopur is thus confined within very narrow limits as to width of deviation. Now the Sursa being only three miles above Captain Dyas's proposed head, it is evident that little additional height is obtainable any where between those points—that torrent therefore must be crossed—aud the most favorable place for a crossing whether above it, or on the level of its bed, is undoubtedly opposite the village of Majree, a little above the line of the old Mahommedan

Canal. The direction of the stream is there perpendicular to the course of a Canal, the banks are less liable to change from the proximity of the low hills, and protecting works in bunds and spurs to confine its vagaries will be necessary only for about a mile above; the bed too is firmer than any where lower down. To cross it here, Colonel Baker's levels showed that we must seek a head of supply higher on the Sutlej than the point whence he commenced; that point also is unsuitable for the site of a permanent head, no unflooded firm ground existing on the right bank of the branch there on which a Dam might abut—it was necessary also to determine on a spot whence the whole dry weather supply of the river might be diverted into the Canal channel. Accordingly after a careful examination of the river and its banks, as far up as Nungal Ghât, I fixed on the Thanna Ghât (on the main stream) as the starting point, and carried a continuous line of levels thence, on a course which seemed practicable, to the Grand Trunk road near Barah, connecting with the upper cross section and the Great Trigonometical Survey bench-mark at the Barah encamping ground. This, with some collateral levels up the beds of nullahs, &c., gave a guide to the selection of the line now recommended—the level of the Sursa at the point of crossing determined in great measure the height at which the Canal must be carried both above and below.

For working out the details of the project certain data were assumed as follows:—

1*stly.—Discharge of the Canal.*—The discharge of the Sutlej at Roopur taken at its lowest, or nearly so, is stated by Captain Dyas to have been—

On the 21st January, 1856,	... ...	2781	cubic feet per second.
12th February, 1857,	... ...	3135	" "
26th January, 1859,	... ...	4027	" "
20th December, 1859,	... ...	4663	" "
21st January, 1861,	... ...	3048	" "

By my own observations it was—

On the 22nd February, 1862,	... ...	3152	" "

And at the Suraee Ghât—

On the 6th March, 1862,	... ...	3122	" "

From these, I think, we may count with safety on a constant supply throughout the year of at least 3,000 cubic feet per second, and considering that the volume of the Sutlej is considerably more than this for eight or nine months in the year, and that water at *any* season is of incalculable

value in the thirsty districts to the southward, it seemed to me advisable to make provision for the conveyance of a larger supply in at least the main channel to the first branch head on the high land. The extra supply has been assumed at 500 cubic feet per second (it might perhaps have been increased to 1,000 cubic feet with advantage) which therefore gives 3,500 cubic feet per second as the maximum discharge at the Canal head to be provided for.

2ndly.—The longitudinal slope of bed and dimensions of channel. These are, I need hardly say, points of paramount importance, the velocity of the stream being determined by their relative proportions. Information is unfortunately very defective as to the effect of running water on different soils. Captain Dyas, however, has given very valuable data in his Memo., taken from actual observation on the channel of the Baree Doab Canal, where the soil is if any thing worse than that of the Sutlej Khadir—he states that the Canal channel at Bheempoor on a curve (of 1 or 2 miles radius I believe) in deep excavation through sand, with a hydraulic mean depth of 4·21, and a longitudinal slope of 1 in 3333·3 seems to stand well, the mean velocity being 3·16 feet per second, or bottom velocity ($\frac{62}{81} \times$ mean velocity) 2·42 feet per second—and adds his opinion that a greater mean velocity than 3 feet per second should not be given to a Canal channel in sandy soil. I have therefore fixed 3 feet per second as the maximum velocity for which the slope of bed and dimensions of the Canal channels are to be calculated, the soil in the Sutlej Khadir being very sandy, as well as a large proportion of that on the branch lines.

3rdly.—Headway for bridges and superpassages.—Assuming that the Canal is to be navigable, 10 feet above full supply level has been fixed as a full allowance for headway, and judging from the height allowed on English Canals, I think it will be sufficient for all the requirements of traffic here.

Description of proposed line from the heads on the Sutlej to the Sursa Torrent.

The site selected for the permanent head works is at a point on the eastern branch of the Sutlej, immediately below the mouth of the Lohund torrent, the level of the bed there being sufficiently high to allow of a slope of 1 in 4800 being given to the bed of the channel down to the

crossing point of the Sursa, supposing the latter to be crossed on the *level*. At first sight, an aqueduct there seemed to be the most advantageous mode of effecting the passage, as it would have carried the Canal free from the silt of the Sursa floods, and at an elevation which would have diminished materially the depth of excavation at the entrance of the bangur; the cost of such a work however would have been very large, fully as expensive as that over the Solanee on the Ganges Canal, without the collateral advantage of high land on either side from which earth for the embankments might be procured; works for a level crossing were therefore decided on.

As the eastern branch carries only a small proportion of the cold weather supply of the Sutlej, it is necessary to divert the main stream into it above the permanent head works. For this purpose the Thanna Ghât is the most suitable site for either temporary or permanent bunds across the stream; the river there runs in one channel with the exception of a shallow film (not above a few inches deep when I saw it in February last) which runs over the shingly bed along the western edge; a low shingle bund would be sufficient to turn this also into the main channel. The bed is of good sized boulders and shingle, and the left bank well elevated above the reach of ordinary floods, though a little water is said to have topped it some twenty years ago (probably in the rainy season of 1842, when the works of the Eastern Jumna Canal suffered so much from the floods); no such event has occurred either before or since in the memory of the oldest inhabitants, the soil is as good as can be expected in such a position and is under cultivation all the year round, the width between the two branches is fully three-quarters of a mile. The stream when I saw it in February last was about 500 feet wide at the surface, with a maximum depth in the centre of 5 feet. The velocity seemed to be about the same as at the Suraee Ghât where I found the maximum at the surface to be $3\frac{1}{4}$ feet per second. An old channel, with a boulder bed, dry except during floods, leads from this point into the eastern branch, through which the whole supply may be turned by a cut 1,100 feet in length, 200 feet wide, with a longitudinal slope of bed of 1 in 916. It is proposed to divert the stream for the present into this cut by means of temporary bunds of shingle, boulders and brushwood, as on the Jumna and Ravee Canals, though it will hereafter, I believe, be found that a permanent masonry work of some kind will in all these cases effect the object more efficiently and economically. The eastern branch where the cut would join it, is about 300 feet

wide, with well defined banks on either side sufficiently high to carry a larger body of water than the river is ever likely to supply, except in the rainy season; the declivity of its bed down to the site of the permanent head works is 1 in 801, over boulders and shingle.

No work will be necessary in the eastern branch to adapt it to our purpose down to the site of the permanent Canal head. The position of this was mainly determined, as I have mentioned before, by the level of the bed of the river there; the annexed sketch taken from actual survey, will I believe make the locality and proposed arrangement of works sufficiently intelligible. The works consist of a Dam bridge across the branch, connected by a masonry revetment with a Regulating bridge at the entrance to the Canal. The Lohund torrent joins the branch immediately above, about 2,500 feet from the foot of the low range of hills whence it makes its exit; the floods of this rao come down with great velocity, carrying with them quantities of sand, shingle and boulders, some of the latter of considerable size. The strip of low land between the foot of the hills and the bank of the Sutlej here is never topped, even in the highest floods, and is so narrow that there is little risk of the torrent ever encroaching on the Canal works; a small channel, shown in the plan on its left bank, dry except in flood, must however be closed by a bund, which, with the raising of the ground thereabout by the spoil from the Canal channel, will make all safe as far as it is concerned. The right flank of the Dam rests on the island on which the village of Koothoopoora is situated; the land here was topped by the floods of last year (the highest on record) but in ordinary floods it remains dry, and a small earthen embankment along the depressed portions at the edge of its banks would effectually prevent this in future. Below Koothoopoora the surface of the island descends rapidly till it is lost in the shingly bed of the river; the old channel, shown in the sketch, taking off on the right bank opposite Keerutpoor, will enable us to turn off the water in the branch, while the head works are under construction. The bed of the branch above, and for some distance below the Dam, is composed of shingle and good sized boulders to a considerable depth; the longitudinal slope of the bed decreases suddenly a short distance above at the foot of a steep rapid, the slope downwards for 2 or 3 miles averaging 1 in 1536, while that above is 1 in 801, a circumstance of no small advantage in constructing a permanent bar across the bed.

It will thus I think be clear that there is little choice of a position for a

permanent head; to have sought one higher up the river would have involved expensive works for the passage of the Lohund, a first class mountain torrent, and the spur of the low hills on which Keerutpoor is situated is about 200 feet high within 50 feet of the water's edge, while below Koothoopoora there is no suitable ground on the right bank down to the Suraee Ghât on which a permanent work might safely abut. By a curious coincidence it is the very spot pointed out by local tradition as the head of the old Mahommedan Canal, adding another instance to the many already existing, of the intelligence of these engineers of a comparatively barbarous age, whose mother wit seemed often to have directed them to the same conclusions as the light of modern science and experience have led their successors to.

The *Dam* consists of a continuous flooring of masonry across the bed of the branch, slightly depressed below its present level; piers 6 feet high and 3 feet thick, dividing the waterway in the centre into twenty-four bays of 10 feet each, three more being situated close to the left abutment to allow of a scour in front of the Regulating Bridge. The total width between the abutments is 700 feet, the remainder of the space being filled up by a masonry weir raised to the height of the piers; giving a waterway of 270 feet in width from the bed to the top of the piers, 700 feet in the clear above that level. The side revetments are carried up well above the level of the highest possible flood; the flooring at the tail of the Dam is depressed so as to form a kind of cistern which may afterwards be covered with a layer of large boulders, with the view of giving a rough hard surface on which the rush of water may partially expend its violence; sloping tail-walls, similar to those so successfully employed by Captain Dyas on the Baree Doab Canal, have been added below. The piers are adapted for the reception of sleepers and falling gates, to retain the water at the height necessary for the Canal supply; the chokies on either flank are intended as godowns for the regulating gear when not in use, and shelter for the working parties attached to the works in the rainy reason.

The *Regulating Bridge* at the Canal mouth is designed with a waterway of 176 feet, the mean section of the Canal stream being 196 feet (as will be shown hereafter), divided into fourteen central bays of 10 feet each, and two at the sides of 18 feet each; I have designed the central bays at a less width than has been usually given in works of this nature, on account of the difficulty which has been experienced in working

sluice gates of larger dimensions, the weight of which, here especially, must have been excessive to stand the pressure of floods rising 13 feet above the bed; the piers are grooved for the reception of gates, and windlasses will be fixed on the top of the piers. The two side openings will be each 18 feet wide to admit of the passage of boats and rafts, and lock chambers with gates of the usual description have been added, down-stream, to give the means of closing up the passages in floods. 10 feet clear headway above full supply is given under the crowns of the arches; a fall of half a foot is designed in the flooring of the bridge to give the stream a set inwards, the increased velocity due to which will I think fully compensate for the somewhat contracted waterway through the arches; the banks down-stream are protected by revetments, sloping tail-walls, and cross curtains. The revetment on the up-stream right flank will be connected with the bund mentioned above, which will be constructed in a continuous line up to the foot of the low hills to protect the works from any possible incursion of the Lohund. The roadway of the bridge is 22 feet wide between the parapets, as the main road up the valley, which at certain seasons is crowded by thousands of pilgrims to the Hindoo shrines of Nundpoor and Nainadavee, must cross here. The greater part of these works will be constructed of boulder masonry in lime cement, boulders being procurable in any quantity from the beds of the Sutlej and Lohund; in the arches, cutwaters and other work requiring close fitting, bricks must be used. The depth of 6 feet given to the curtain, tail-walls, &c., will I believe be ample in so good a soil; the spoil from the Canal excavation will be sufficient to fill up the old side channels of the Lohund behind the bund, and raise all that space well above the level of any possible flood.

The *dimensions of the Canal channel* from the heads to the Sursa have been calculated for a maximum discharge of 3,500 cubic feet per second, with a mean velocity of 3 feet per second on a longitudinal declivity of 1 in 4800, the bottom width being 190 feet, with a depth of water at full supply of 6 feet; the tow-paths, 15 feet wide on either side, will be kept at a constant level of 2 feet above the full supply; the road banks will in general be on the level of the natural surface, raised wherever necessary, so as to be nowhere less than 2 feet above the tow-paths. The soil is so sandy from a short distance below the head, that I do not think it advisable to exceed the limit of 3 feet per second

in velocity of current, hence the great width given to the channel. The formulæ, on which this and all other similar calculations throughout the project have been based, will be found in Appendix A., and the detail and points of change of section will be found in the Tabular Statement at the end. The longitudinal slope of bed might have been diminished on this line by the construction of an overfall which would have rendered a less width of channel necessary; the present arrangement seems to me preferable. The distances marked off on the central lines of Canal on the map, show lengths of 5,000 feet, which I have adopted as on the Baree Doab Canal, instead of the mile, for greater convenience in calculation. The sheets of longitudinal sections of Canal channels give full information as to depth of excavation, levels of bed of nullas, flooring of dams, springs, &c.

Between the 1st and 2nd five thousand an *Inlet* will be required, to admit drainage water from the low hills on the left bank which there is no other mode of getting rid of. It is designed with a waterway of 50 feet in the clear, and a perpendicular drop into the Canal, the crest of which is raised above the full supply level; nearly the whole of this may be built of boulders.

A *Wooden Bridge* with a roadway 12 feet wide will be necessary at the 2nd five thousand, for the country traffic and to give a passage to the Suraee Ghât immediately opposite; the spans for this and similar bridges elsewhere have been designed with reference to the length of the timbers usually procurable, about 15 or 16 feet; two of these scarfed in the centre, strengthened by a straining beam and side struts, will be sufficient to span a 30 feet bay, the number varying according to the width of the roadway; over these may be laid kurries and boarding, or any material which may be found most economical according to locality; the uprights supporting the roadway beams will rest on narrow piers of masonry built in the channel up to the level of the tow-path; the passage along the tow-paths will be left free on either side. This form of bridge will, I think be found the simplest and most economical which could be devised; it can be put up by common workmen without difficulty, and though not regularly trussed, is strong enough for all the purposes of the country traffic. Other than temporary structures they do not pretend to be. I have only adopted them in accordance with my instructions, which were, if I understood them aright, to design

every thing connected with the Canal on as economical a scale as possible, except those works on which the efficiency and security of the water supply depended. These latter it would of course be false economy to construct other than of the best and most lasting description.

Below this bridge the line crosses the Uttaree Nullah, a mountain torrent draining the uplands near Hindour, about 200 feet wide, with an average depth of 4 feet; the declivity of its bed, nearly 1 in 602; the soil is of shingle, earth, and small boulders; a very small stream of water was running down it when I crossed. As this is so close to another torrent, the Kalee Koondwalee (or Koklee of Colonel Baker) a *Cut* 100 feet wide, is designed to turn it into the latter; the length would be 5,800 feet, with a declivity of 1 in 661, in good firm soil; the banks at the head of the cut are high, far above the reach of any flood, so that although the diversion of the stream must necessarily be very abrupt, I think it may be done without much risk, if the bund across the channel be carefully looked to for the first few rainy seasons.

At the 4th five thousand we come to the Kalee Koondwalee Nullah, which must be crossed by a *Dam*, the Sutlej here approaching so close to the low hills that the back-water from its floods extends up the bed of the torrent almost to their foot; the position will be best explained by the annexed sketch, which shows the limit of the Sutlej floods on the banks below the village of Beylee. There is no record of any flood having risen beyond this limit and the ground on the line of Canal is several feet above that level; the longitudinal slope of the bed is nearly 1 in 390 where the line crosses, yet such is the influence of the back-water from the floods of the Sutlej, that little but sand is to be found in the bed, although not very far up within the hills, boulders and shingle are brought down in large quantities. The bed of the Canal here passes about 4 feet below the present bed of the torrent; this, awkward as it confessedly is, could not be avoided; to cross anywhere lower down the torrent would bring the line into too close proximity to the current of the Sutlej floods; the only disadvantage attending it, however, is the chance of silting up after a flood has subsided, which the rush of water through the Dam will in a great measure obviate.

The works projected here consist of a *Dam* and *Regulating Bridge* as at the heads, with bunds and spurs on either bank of the torrent above the Canal line, to keep the direction of floods as nearly as possible perpendi-

cular to the Dam. Now as to the *waterway* necessary here for the passage of the floods of both torrents, if the discharge of the Kalee Koondwalee alone be calculated from the area of its flood-water section, with the velocity due to the declivity of its bed, the result is nearly 11,500 cubic feet per second, a quantity manifestly much in excess of what could possibly be brought down by such a drainage line: I have therefore taken Sir Proby Cautley's datum of the discharge due to a maximum rain-fall of half an inch per hour, over the whole area of catchment basin, or 323 cubic feet per second, per square mile of area. On this the calculations for the waterway of all the Canal works in the Ganges Khadir were based, (*vide* his last Report on the Ganges Canal,) and as those works have stood the test of 10 years successive floods uninjured, I think we may now assume it to be a safe limit. The aggregate area of the catchment basins of the Uttaree and Kalee Koondwalee Nullahs being then (as taken from the Revenue Survey maps) about 31½ square miles, the maximum discharge would be 10,237 cubic feet per second. To pass this off, a waterway has been given to the Dam of 200 feet divided into twenty bays of 10 feet each, by piers 3 feet thick and 6 feet in height; over the top of the piers there is a clear passage of 350 feet in width between the abutments.

The *Regulating Bridge*, to prevent the passage of floods from the torrents down the Canal, will have a total waterway of 206 feet (the mean waterway of channel being 196 feet) divided into seventeen central spans of 10 feet each, and two of 18 feet at the sides for the passage of boats, &c.; a greater waterway has been given here than at the heads, where the velocity through the bridge will be accelerated by the overfall in the flooring, which it is not considered advisable to adopt here, on account of the very sandy nature of the soil; with an increased velocity below this bridge the banks on either side would undubitably be cut away for some distance, unless protected by masonry or piling. All deep foundations in both Dam and Regulator must be based on under-sunk wells, water being found close to the surface; they have been projected 15 feet below the level of the Dam flooring, a depth sufficient I think to secure them from any possible disturbance in this locality. The actual height of the wells will be only about 9 feet, as it is possible to lower the surface level of the springs 6 feet below the Dam flooring. The foundation above will be formed by a casing of masonry filled in with dry boulders, the flooring 2·5 feet thick over all.

I have adopted the old round form of well in place of the "block" in all foundations of this nature, as the most economical, from its now well known superiority in facility of under-sinking.

Between the Kalee Koondwalee and the Sursa, provision must be made for the disposal of a small amount of drainage from the low hills in the vicinity of the fort of Bhurtpoor; *two Inlets* similar to that near Boonga of 50 feet waterway each, will I think be sufficient. It is possible to pass this drainage under the Canal and so get rid of some silt, but the cost of syphons with so great a width of channel would be considerable, an expense which we should be hardly justified in incurring considering that the reservoir formed in the Sursa will intercept a large proportion of the deposit which may be thus brought down in floods.

A *Timber Bridge* for cross country traffic will be required somewhere near the village of Kot; it will be similar in all respects to that near Boonga.

At the 9th five thousand we reach the Sursa, by far the most formidable of the obstacles in the Sutlej valley; the width of its flood waters is here upwards of a mile, the central current running with a velocity due to a declivity of 1 in 638; the bed generally sand with a sprinkling of shingle and boulders; patches of boulders at varying depths are met with, but they are few and far between; quick-sands are numerous, so that it is dangerous crossing after even a small flood except at the spots used for the purpose by the villagers; the annexed sketch with the longitudinal and cross sections in the sheets of sections will give a very fair idea of its size and capacity. Four torrents combine to form the stream as we find it in the valley; the junction of three of these is effected in the low hills about 3 miles above the Canal crossing; two are comparatively insignificant, draining a length of about 6 miles of the hills on either side; the central channel, which retains its name after the junction, drains a valley some 20 miles long behind the outer range of hills, from the watershed of Pinjor; the fourth affluent joins it just above its exit from the hills, carrying into it the drainage from some 10 miles of the hills towards Hindour. The declivity of its bed diminishes very rapidly from the village of Indurpoor to a little below the crossing of the Canal, whence to the Sutlej the slope is tolerably uniform. Our levels show that the level of the bed here has not altered since Colonel Baker observed it twenty years ago; shingle and

boulders are visible in the bed about half a mile above the Canal line, rapidly increasing in size as we ascend the course of the stream, clearly pointing out, I think, the safest site for any permanent works in its bed; nearer the hills indeed it would be hardly possible to carry the line, as a reference to the large map will show, and every foot lower down adds to the depth of excavation in the bangur; the bunds in the sketch, show the extent to which it will be necessary to provide protective works; above their upper extremities the land on either side is high, out of all risk from floods. It is evident from the section that a large proportion of the present wide channel cannot be occupied in floods by a stream running with any great velocity; the existence of sand beds and sandy islands to such an extent in a torrent with so great a declivity puts it out of the question; in fact calculating the discharge by the area of this flood section, and the velocity due to the observed declivity of the central channel, we obtain the enormous amount of 129,548 cubic feet per second, a discharge equal to that of some of the first class rivers in Europe. Here, therefore, I have assumed, as in the case of the Kalee Koondwalee, the maximum discharge to be provided for, as that due to a rain-fall of half an inch in depth over the whole area of catchment basin.

The works projected for the passage here are similar to those at the head and Kalee Koondwalee—a *Dam* provided with sluices for the passage of the floods of the torrent, with piers sufficiently high to retain the Canal supply—and a *Regulating Bridge* to prevent more than the required supply passing down the Canal. The bed of the torrent having apparently remained at the same level for the last twenty years the floorings of the Dam and Regulating Bridge, as well as the plinths of revetments, &c., up-stream, have been projected on the present level of the bed at the crossing. The discharge to be provided for being that due to the half inch rain-fall over a catchment basin about 26 miles long by $9\frac{1}{2}$ miles wide ($= 247$ square miles) or 79,781 cubic feet per second, a waterway of 920×7 is given through the piers of the Dam, and a clear width over the top of 1,213 feet between the abutments; which it will be observed corresponds very nearly with the width of the central channel of the torrent at the point of crossing. With this waterway, the calculated afflux in the highest known flood ($6\frac{1}{2}$ feet above the level of the Dam flooring) would not raise the

water level higher than 2 feet above the top of the Dam at most. The bunds and spurs on either side, up-stream, will be so arranged as to direct the flood current perpendicularly on the line of Dam, the present side channels being closed by the same means. The island on which the Regulating Bridge will be situated, is submerged in high floods to a depth of about $1\frac{1}{4}$ feet; that on the left flank from 2 to $3\frac{1}{2}$ feet.

The foundations of the Dam and its revetments will be sunk to a level of 15 feet below the sill, the surface of the springs, which here is kept at the level of the bed by the small perennial stream from the hills, can be lowered about 6 feet by a drainage cut, so that it will only be necessary to undersink for a depth of 9 feet; the foundations above this being completed to the level of the sill by masonry walls under the front and rear of the line of piers, connected at intervals by cross walls, the intervening spaces being filled up with boulders laid dry, covered at the top by a layer of masonry sufficiently thick to withstand the erosive action of the current, and filled with incompressible material. A like construction has been adopted in all full foundations where the width is considerable; the expense of these undersunk foundations, it will be seen from the estimate, forms a large proportion of the total cost of the works—they cannot, however, be dispensed with in such a soil. The circles on the plans show the position and number of the wells. The width of the Dam (1,213 feet) is divided into ninety-two bays of 10 feet each, divided by piers 3 feet thick—a platform 10 feet in width adjoining each flank revetment. The top is on one uniform level of 7 feet above the flooring; the length of the piers $18\frac{1}{2}$ feet; grooves, &c., are provided for the reception of sluice planks and falling gates; the chokies on either flank are intended for the reception of the sluice gear when not in use, and as shelter for the working parties; a curtain is sunk to the full depth the whole way across, 40 feet below the line of piers, connected with the foundations of the side revetments; sloping tail-walls are added for further security. The form of raised weir, instead of additional sluice openings at the flanks of the Dam, designed in the Dam at the head works, I do not think it advisable to adopt here in consideration of the violent action of a fall of water on so sandy a bed. The space between the Dam and curtain wall, down-stream, will be covered with a layer of boulders, the lowest course, laid in mortar, to protect the foundations from the risk of being undermined; a

thin water-proof flooring, well protected from the impact of the current, would be sufficient I believe in most cases to preserve the under soil from all erosive action.

The *Regulating Bridge* is designed with a waterway of 186 feet (the mean waterway of the Canal channel below being 177 feet) divided into fifteen central bays of 10 feet each, and two at the sides of 18 feet each, for navigation purposes. The initial velocity of the current being here very much diminished by its passage through the large reservoir which will be formed in the Sursa, a fall of half a foot is given in the flooring of the bridge to increase the velocity of entry; with this aid, the waterway will I think be found ample. The bridge will be all of masonry, arched across, a clear headway of 10 feet being left from the soffits of the arches to the surface of full supply; the 10 feet bays will be closed in floods, with gates worked by windlasses fixed on the top of the piers; two gates each $3\frac{1}{2}$ feet high for each bay, with sleepers to be laid on top in case of an extraordinary flood; the regulation at the side openings will be effected by lock gates in chambers, down-stream, as at the heads; the width of roadway above will be 20 feet between the parapets. Revetments, sloping tail-walls, and cross curtain, with dry boulder flooring, are designed for the protection of the banks and bed down-stream. The foundations will be laid at the same level, and in the form described for the Dam, excepting the revetment and tail-walls in the Canal channel down-stream, where it appears sufficient to give them a maximum depth of 8 feet, which can be effected without having recourse to undersinking, the deep foundations of the bridge and its up-stream revetment affording ample protection to this part of the works from the floods of the torrent. The revetments, up-stream, will be built up 10 feet above the level of the Dam flooring with a parapet 2 feet in height, making the total height 12 feet, sufficient I think to secure the works from being topped by any possible flood. The bunds to confine the torrent will be connected on the left bank with the bridge revetment; on the right, with a paved slope protecting the left bank of the Canal channel at its entry. The mass of these bunds will be formed of shingle, clay and sand, with a paved slope in front, further protected at intervals by spurs of crib-work filled with boulders. A small quantity of drainage from the land on the left bank of the torrent will have to be passed off either over or through the bund —where and how can best be determined at the time of its construction.

FROM THE SURSA TO THE BRANCH HEAD AT SURRANAH.

The longitudinal slope of the bed below the Sursa having been fixed at 1 in 6000, with reference to the relative levels of the beds of the drainage lines and surface of the high land lower down, the consequent dimensions of channel for a discharge of 3,500 cubic feet per second, with a mean velocity of about 3 feet per second are—

Bottom width, ...	170	feet.
Depth of water at full supply, ...	7	„

with side slopes of 1 in 1, tow-paths on each side 15 feet wide, the top surface being kept at a uniform level of 2 feet above the full supply, by excavating or raising according to circumstances.

A reference to the map will show that the spur of the low hills on which Roopur is situated, running out to the edge of the Sutlej, divides the drainage of this portion of the valley into two distinct sections. The upper portion, between the Sursa and Roopur is carried off by five torrents, whose sources lie some 2 or 3 miles within the range of low hills, of no great size individually, though their aggregate capacity is considerable. They all run in sandy beds on very steep declivities; the one nearest the Sursa, locally named the Gunowlie Khud, brings down immense quantities of sand, or rather spreads its silt over a very large surface, immediately below the crossing point of the Canal; the sand lies there in huge mounds, and the villagers of Nooho complain bitterly of its inroads on their land within the last few years. The largest of the five and that which carries the greatest volume of water, is that near Chundpoor, about a mile and a half further on. The declivities of their beds are as follows:—

Gunowlie Khud, ...	1 in 320 to 1 in 446
Chundpoor, ...	1 in 209
Mullikpoor, ...	1 in 223
Ladoal, ...	1 in 226
Hooseinpoor, ...	1 in 324

The valley of the Hooseinpoor Khud is depressed considerably below the others; the depression continuing close into the foot of the low hills. Now, to construct superpassages or aqueducts for the separate passage of each of these torrents, would involve a very heavy expenditure; and level crossings, even were they practicable, are out of the question with flood water so heavily laden with silt; the foundations of any works besides, con-

structed across beds on such steep declivities would be constantly exposed to the risk of being undermined by floods. The safest and most economical course appeared to me therefore to be, to collect all the separate drainages into one channel if it were practicable, and pass the Canal over the combined stream by an aqueduct. This the levels showed the possibility of; the Hooseinpoor Khud affording the necessary outfall, secured by the depression of its valley from any risk of flooding the lands on either side. A cut or catch-water drain 22,700 feet in length, is accordingly projected from the Gunowlie Khud into the Hooseinpoor Nullah, which will intercept all drainage crossing it from the low hills; the declivity of bed would be 1 in 466 from the Gunowlie to the Chundpoor Khud, thence onward to the end 1 in 497. A short junction from the Ladoal Khud, will I think be necessary in addition, the present channel meeting the Gunowlie cut, at an awkward angle. The discharge of the outfall channel has been calculated as in the case of the Sursa, from a half-inch rain-fall over the whole catchment basin, as taken from the Revenue Survey map, about 4 miles × 3 = 12 square miles; this amounts to 3,876 cubic feet per second, for which a channel, 100 feet wide with 5 feet depth of water and side slopes of ½ in 1 on the given declivity of 1 in 497, will suffice, the widths of the cut will vary as follows:—

From Gunowlie to Chundpoor Khud,	 60	feet.
Chundpoor to junction of Ladoal,	 80	"
Below Ladoal cut,	 100	"
Width of Ladoal cut,	 30	"

the present channels of the several Khuds will be bunded across by embankments formed of the spoil from the cuts, protected by spurs at each crossing. If these points be carefully looked after for the first few rainy seasons, no fears need be entertained for the safety of the embankments; silt will doubtless be deposited in considerable quantities at first along the cut, but in course of time the floods will regulate the level of the bed to the slope best suited to the varying discharge and velocity. The several cuts have been made sufficiently large to lead the streams in the proper direction, leaving the floods to widen them to the requisite dimensions.

The *Aqueduct* to carry the Canal over the outfall, will be situated a little in advance of the 15th five thousand; the aggregate water-way below is 105 feet, divided into three spans of 35 feet each, by piers 6 feet thick; the passage for the Canal above is 180 feet in total width, divided into two channels, each 90 feet wide by a central pier 4 feet in thickness, which

will allow of repairs being made without shutting off the whole Canal supply; passages are arranged for on either side, on the level of the tow-path (9 feet above the Canal bed), 4 feet in width on the left, 10 feet on the right bank; the greater width on the right bank being given to admit of the passage of wheeled vehicles; corbels, 2 feet wide on the Canal side will somewhat increase these widths and afford space for a railing, which may hereafter be found necessary, without encroaching on the width of the passage; the parapets, 2 feet high, will be projected clear of the head walls of the aqueduct. The difference of level between the beds of the Canal and outfall channel is 14·79 feet, which is thus disposed of:—

Height to springing of arches, ...	6·00
Rise of arches (segment of 60°), ...	4·69
Thickness of arch, ...	3·00
Brick-on-edge and flooring, ...	1·10
Total, ...	14·79

The flooring will be composed of asphalte or some substance impervious to water; the velocity of the current being so small, there will be little danger of even puddle being washed away; passages in the masonry above the piers will be arranged for in the course of construction to carry off any leakage from the backing of the arches; the puddle backing to the abutments will be continued under the Canal bed for a length of 60 feet from the masonry, up and down-stream, covered over with a layer of boulders or kunkur; no flooring under the arches has been deemed necessary as the tendency will, I think, be rather to silt up than excavate. The foundations will be wide shells of masonry filled with boulders or kunkur, resting on a stratum of shingle or boulders, which a trial well sunk on the spot showed the existence of; water-wings, 30 feet long, sunk to the same depth, are added, up and down-stream, to secure the wing-walls of the work from injury; their foundations being only carried down to the level of the bed of the outfall channel. The mass of the work can be built of boulders or blocks of kunkur and hard conglomerate, procurable from the ravines in the neighbouring low hills. The longitudinal section of the Canal channel shows, that the bed meets the ground surface about 1,000 feet above, and 2,000 feet below, the aqueduct, the maximum difference of level being about 8 feet. To secure the embankments from the ravages of rats and other vermin, a wall or core of sand, 4 feet in thickness, extending from the ground surface up to the level of full supply in the

Canal, will be carried through the centre of the embankments right and left, from the wing-walls of the aqueduct to the points up and down-stream, where the Canal is again under soil. This expedient I believe has not yet been tried in Irrigation Works in these provinces, but in both America and Holland it appears to have been long known and practised successfully. The embankments being sufficiently thick to prevent all risk of percolation, the only danger to be apprehended is from holes burrowed by rats, moles, and other vermin. If a masonry wall be substituted for the sand, as was done by Captain Dyas in an embankment a mile long on the Baree Doab Canal, the cost would be, supposing it to be only 1½ feet thick, and built at the lowest possible rate, fully eight times greater. It will not be necessary to fill the space between the embankments right and left up to the level of the bed except a length of about 250 feet, up and down-stream, from the aqueduct; bars 15 feet wide will be formed at intervals up to that level to stop any current below, the remaining space may be left to be filled up by silt deposits from the Canal stream.

About a mile below this aqueduct we come to the watershed of the Roopur spur, between which and the point of the bangur near the village of Sulowra, three sandy torrents, two, the Soogh and Boodkee, of considerable size, cross the valley. The average declivities of their beds are as follows:—

Roopur Nullah, ...	1 in 318
Soogh, ...	1 in 311 and 1 in 429
Boodkee, ...	1 in 526

These it is proposed to deal with similarly to the drainages above Roopur; as level crossings, though practicable, could not be recommended where sand is brought down in such quantities, as is apparent from the huge ridges lining the banks of these torrents; it would besides involve a very awkward lining out of the Canal channel in a soil for the most part of pure sand. The Roopur Nullah being on the most depressed level of the three and lying close to high land, by which the length of embankment for the Canal is reduced to a minimum, its channel has been chosen for the outfall cut, into which the Soogh can be diverted by a cut above the high land on which the town of Kotluh stands; and the Boodkee by another, commencing from the village of Rungheelpoor, which would join the outfall close above the town

of Roopur;* the lines for these cuts were selected after a careful examination of the localities and levels. I do not think they could be altered with advantage; a reference to the map will explain their positions more clearly. The cut from the Soogh would be beyond all risk at a distauce of about 1,000 feet below its head, as it there enters a valley bounded by high hills on either side; its channel for this 1,000 feet is projected at 200 feet in width, the remainder down to the junction with the Boodkee cut, 100 feet wide, with a declivity of bed of 1 in 373. The Boodkee cut takes off from a point where the current of the torrent sets directly into it; the channel is estimated at 200 feet in width for the first 1,000 feet, the remainder contracted to 100 feet, on a uniform declivity of 1 in 661. The present channels of the torrents will be blocked below the cuts by earthen embankments protected by spurs of open piling similar to those employed so successfully in the Sombe torrent above the Western Jumna Canal works at Dadoopoor; the effect of a silt bearing stream with such a construction being to deposit sand at the foot of the embankments in rear of the spurs. For the calculation of the combined discharge of the outfall channel we have a catchment basin about 10 miles long by 7 miles wide, or 70 square miles, which, with the rain-fall we have hitherto assumed, would give a maximum discharge of 22,610 cubic feet per second; for this a channel 350 feet wide, with a depth of water of 6 feet, and a declivity of bed of 1 in 425, will suffice, (the declivity is the mean of the slope of bed, above and below the Canal crossing, the former being 1 in 373, the latter 1 in 478); the cut will only be excavated to a width of 250 feet.

The *Aqueduct* to cross this outfall will be situated between the 16th and 17th five thousands, about ¼ mile below the town of Roopur. The required waterway under the aqueduct being 350 feet, the work is projected in 10 spans of 35 feet each, divided by piers 6 feet in thickness. The depth from the Canal bed to the bed of the outfall channel, is thus divided :—

Height to springings of arches, ...	6·00
Rise of arches, ...	4·69
Thickness of arch at crown, ...	3·00
Brick-on-edge and flooring, ...	1·00
Total, ...	14·69

The trial-well sunk here, showed nothing but tolerably firm clay below a depth of 3 feet from the present bed of the Nullah; it has been therefore considered sufficient to give the foundations the same depth as at the aqueduct above Roopur; all other details are the same as described for that work.

The drainage of the strip of land lying between the Boodkee cut and the Canal line must be provided for before reaching the Sulowra point; the quantity draining off so sandy a soil with a very small declivity of surface cannot be very great; an inlet of 50 feet waterway, similar to that at Boonga, on the left bank, where the channel of the Boodkee now crosses, will, I think, be sufficient. An outlet of the same waterway is estimated for on the opposite bank, to give egress to any extraordinary amount of flood water.

From the Sulowra point the line would keep close to the foot of the high land so as to retain the surface level of the water within soil; another inlet will I think be necessary here, unless it be found practicable by means of catch-water drains, to divert the drainage from the ravines off the Canal line; the estimate will, I believe, cover any expense on works of the kind which may be found necessary.

At the 23rd five thousand, we come to the Seesooan torrent, where a *Superpassage* is projected; the Canal bed being at a sufficient depth below the bed of the torrent. Just before meeting it, the line passes through a spur of the high land with a maximum depth of excavation of 43½ feet; this, I would have avoided, had the levels of the bed of the Seesooan admitted of it, and so saved a length of half a mile of deep excavation; but the rapid fall in the bed of the torrent precludes the possibility of carrying the line further to the westward. The declivity through the contracted channel above Dolchee Majra (at one place it is only 100 feet wide) is 1 in 549, below which it continues tolerably uniform at 1 in 794; westward of the Canal crossing, it again increases where the channel emerges into the low land of the Sutlej valley. At the point where Captain Dyas's levels crossed, the bed is raised above the level of the adjoining land by the quantity of silt annually brought down in floods; the sand heaps at the site of the superpassage are of no great depth, but from Balsinda downwards, the banks are lined by enormous ridges, some 20 and even 30 feet in height. The torrent takes an abrupt turn just in advance of the contracted channel which brings the flood current in contact with

the Canal line at an awkward angle. To remedy this a cut will be necessary, about 4,000 feet in length, commencing in the high land on the left bank opposite the village of Dolchee Majra, 150 feet wide for the first 500 feet, 100 feet for the remainder; the present channel will be closed by an embankment (formed of the spoil) just below the mouth of the cut; this must be so situated as to intercept the drainage water which comes down a deep ravine on the right bank, from the high land near the village of Solkeean; a reference to the map will show the position of this cut terminating on the superpassage. The Seesooan receives very little surface drainage below the point where it takes a westerly course, the fall of the country on the left bank being all to the south-west, while the edge of the Boodkee valley approaches close to the right bank of its northerly feeder, a small torrent passing by the village of Seealbah; taking then the catchment basin to be 8 miles in length by 3 miles in width, we obtain an area of 24 square miles, which would give a maximum rain-fall to be carried off of 7,752 cubic feet per second, agreeing very closely with the discharge calculated from the area of the section at the Canal crossing, with the velocity due to a declivity of 1 in 794; to pass off this discharge, a waterway of 150 feet wide by $6\frac{1}{2}$ feet in depth, on the given declivity of 1 in 794, will be required.

The difference of level between the beds of the Canal and the torrent is 21·93 feet, which is thus disposed of:—

Depth of water in Canal, ...	7·00
Headway up to soffit of arch, ...	10·00
Thickness of arch, ...	3·00
Brick-on-edge and flooring, ...	1·93
Total, ...	21·93

The Canal channel will be spanned by three central arches of 45 feet span each, and two at the sides of 32 feet each; tow-paths $7\frac{1}{2}$ feet wide in the clear will be carried under each side arch, leaving an aggregate waterway of 184 feet. The mean waterway of the Canal channel is only 177 feet; the addition is made in this work, in consideration of the impossibility of increasing its dimensions should the Canal be required to carry a larger supply hereafter. The waterway for the torrent above, is projected in one channel 150 feet wide at bottom, with side walls (head walls of the work) 10 feet in height, 5 feet thick at the base, 4 feet at top; the flooring over the arches will be

formed as in the Roopur aqueducts, except that the upper surface, being exposed to the action of a more rapid current, must be made of some hard material, probably a layer of kunkur slabs; the backing of the abutments will be of puddled clay covered with a flooring of kunkur, slag or boulders, packed in cribs. The foundations of piers and abutments must here be undersunk, the surface of the springs lying some 5 feet above the level of the Canal bed, below which it will not be possible to drain. I was not able to get a trial-well sunk, owing to the lateness of the season, (the middle of last June,) when those higher up the line had been completed; there is little doubt, however, that nothing except sand will be found at that depth in such a locality. The foundations of the wing-walls need not be carried lower than the bed of the Canal at their junction with the abutment, thence diminishing upwards by steps, as shown in the plan; the tow-path retaining walls being quite separate from the body of the work, and having no weight to support, will not require foundations deeper than 4 or 5 feet, which may be laid in with the aid of pumping; the wing-walls will be carried out sufficiently far, up and down-stream, to keep floods well away from the edge of the Canal excavation; crib-work revetments, 130 feet in length, with spurs, will be added at their extremities to preserve the banks from cutting and keep the current in the proper channel.

On the left bank of the Seesooan valley, at the 24th five thousand, the line enters the *Bangur* with a maximum depth of excavation of 44 feet, diminishing to 32 feet at the point fixed on for the site of the first branch head, 1,600 feet in advance of the 29th five thousand. This deep excavation has, from the first, been one of the main difficulties of the project, not only on account of the heavy expenditure involved, but also the numerous disadvantages attending deep cuttings in sandy soil. The depth on the present line, I do not believe it possible to reduce, considering the levels of the Canal bed with reference to those of the drainage of the Khadir. The channel is carried down to the Surranah branch head with a uniform bottom width of 170 feet, side slopes of 1 in 1, with berms 15 feet wide on either bank, excavated to a uniform level of 2 feet above the calculated full supply; the slope of the cutting, up to the ground surface being 1 in $1\frac{1}{2}$. I had at first projected the width of berm at 20 feet, to give room for any slipping which might take place in the sandy slopes, but

have diminished it in the estimate, solely on the score of expense, to a limit, below which I do not think it can be safely reduced.

Five *Bridges* will be required to keep up cross communication on this section of the line, two with a roadway 20 feet in width, for the roads from the Roopur Ghât to Buddee and the town of Roopur; for the rest, a roadway 12 feet wide will suffice; all will be of timber resting on low masonry piers as before described.

The *widths of land* for the line have been calculated with reference to the space required for the disposal of the spoil from the channel excavation, giving a clear width of 30 feet from the edge of the cuttings to the foot of the spoil bank, part of which will be occupied by the Canal patrolling road; and a road 20 feet wide, outside the spoil bank along the boundary ditch, to give a passage for the country traffic. These widths will be:—

From the heads to the commencement of the deep excavation at the 22nd five thousand,...	600 feet
Below that, ...	1,300 „
Diminishing gradually to, ... at the Surranah branch head.	900 „

From the heads to Roopur, the right bank boundary road must be widened to 30 feet, as it will take the place of the present main road along the valley which the Canal will cross at several points. These roads are entered in the estimate as a separate item; the experience on other similar works has fully proved that they are absolutely necessary.

An Escape would have been projected from the central channel above the Surranah branch head, had it been practicable; the Sursa, however, will afford the means of regulating the supply entering the channel, and with the aid of the small outlet at the Boodkee, in carrying off the small amount of drainage let in there, I think the works may be considered quite secure.

Four 1*st class* and three 2*nd class Chokies* will be required on this section of the line. A 1st class at the head works, another at the Sursa, and a third near Roopur, the fourth at the Surranah branch head. One 2nd class near the bunds at the Thannah Ghât, a second at the Kalee Koondwalee crossing, and a third at the Seesooan superpassage. The cost of temporary shelter for the native Establishment and workmen will be covered by the per centage on the works.

Workshops on an extensive scale will not, I believe, be necessary, as

any heavy wood or iron-work required, can be made up in the Baree Doab or Ganges Canal Workshops; all *ordinary* work of this description, however, can be executed more cheaply on the spot, as the expense of carriage will be thereby saved, and a range of workshops has therefore been estimated for.

The land required about these buildings has been estimated at 5 acres for each 1st class chokie, 2 acres for each 2nd class; for workshops, the same as for a 1st class chokie.

Plantations have not been estimated for, on the score of economy, not being an absolutely necessity; a small monthly expenditure would, however, afford the means of maintaining nurseries of young forest trees, which might be planted out during the construction of the works wherever water was near at hand, and along the banks generally after the admission of the Canal supply.

At the Surranah branch head, this portion of the project properly speaking ends. Though included in the estimate for the passage of the Khadir, the details of the regulating bridge and the reasons for fixing it at Surranah will be more appropriately considered along with the detail of distribution over the several branch lines; the channel up to this point will carry the full supply of 3,500 cubic feet, as it does not seem advisable to expend any in irrigation in the Sutlej valley where rain is plentiful and the springs near the surface, while every available drop would be of untold value to the thirsty districts below. The level of the surface of the water in wells lying near the Canal line is shown in the longitudinal section. It is everywhere either very near, or above the Canal bed up to the entrance of the high land; this is a favorable circumstance insomuch that it will diminish to a great degree the loss by absorption, which otherwise, in so sandy a soil, would have been considerable.

(To be continued)

No. LXVI.

VENTILATION OF BARRACKS AND JAILS.

On the Possibility of Ventilating and Cooling Barracks and Jails, by means easily available in India and at small expense. BY MAJOR F. DE BUDE, R.A.

AIR exhaled from the lungs and given off from the surface of the bodies of animals is hotter, and consequently lighter than the surrounding air, and therefore rises.

The air therefore in a room occupied by human beings is coolest and purest near the floor, hottest and most vitiated, near the roof.

While this rule holds good for all rooms in both cold and hot countries, (England and India for example,) there is this difference, that in a cold country the air inside a room is almost always warmer than the external air; consequently ventilation can be secured by means of the chimney, or better still by some outlet near the roof.

In India the outer air is through a great part of the year hotter than even the vitiated or hottest air inside a room; which, consequently, being heavier, would not rise and escape even if outlets were left for it in or near the roof.

But even in England it has been found necessary to adopt some plan for drawing off the vitiated air, other than merely leaving holes for its escape.

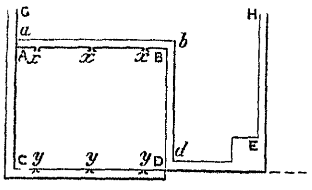
Dr. Reid's plan of ventilation in England as applied to the Houses of Parliament and other buildings, is this—

Let AB be the roof, and CD the floor of a room.

A pipe, *ab*, with holes *x*, runs along the roof AB down one side BD, and communicates with a furnace E and chimney EH.

Another pipe runs along the floor CD, with holes y, opening into the room, up the side AC and above the roof to G.

The air in the chimney EH, being heated by the furnace, rises, and its place is occupied by the vitiated air in the room, rushing through the holes x into the pipe *abd*, and bottom of furnace.



The doors and windows of the room being closed, the air drawn off by the furnace is replaced by that flowing down the tube GCD, and into the room by the holes y.

Thus a constant stream of fresh air is kept up which pervades every part of the room. The bad air rises naturally to the top and is as constantly drawn off. No portion of the vitiated air is breathed a second time.

The only plan of ventilation adopted in India is this, (stirring the air by means of punkahs does not constitute ventilation)—

The mouth of a thermantidote (or revolving wheel with fans) is introduced into the room through a hole in a wall or door. The outer air is sucked in at the axles by the revolution of the wheel and blown into the room through the mouth, and this air is cooled by passing through wet tatties into the thermantidote. All doors and windows are kept shut to exclude heat, dust, and flies. Now it is evident that if air be constantly blown into a room, a corresponding proportion must find its way out somehow, and thus a sort of ventilation ensues.

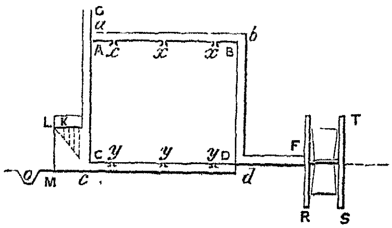
But it must be remembered that the windows are tightly shut; that the doors, through the chinks of which, the greater part of the air must escape, are near the bottom of the room, and that the cold air which comes in at the mouth of the thermandidote naturally remains near the bottom. It therefore follows that the greater portion of the air which finds its way out, is the recently introduced fresh air, while the worst and highest is scarcely touched, and that part of it being acted on by the eddy produced by the thermantidote, is drawn down as it gradually cools and is re-inhaled again and again before it gets out.

If this be true, the English plan is far better than the Indian

one, and there appears no difficulty in the way of its adoption in India.

First, to cool the air in its passage to the holes y in the floor, let it pass through a tattie CL, in a small chamber CLM.

A trough at K with holes for the water to drip through on to the tattie, and a cistern O to drain the chamber, and from which the trough K could be constantly refilled would complete the apparatus. At the other end of the building would be either a furnace and chimney, as shown in the previous figure, or a thermandidote, as here shown; but which, instead of driving air *into* the room, would be used to exhaust air *from* the room. Unless, however, fuel is very dear, the furnace plan is decidedly to be preferred, and there is no reason why the furnaces for ventilation should not be applied to the purposes of cooking as well.



That a thermantidote has great power in exhausting a tube, is shown by the fact that it is used in England for that purpose.

In a railway described in a recent number of the St. James' Magazine, the carriages are driven by means of a pipe exhausted in this very way. The space round the axle at one side opens into the pipe; the other side is closed. The wheel a very large one, worked by steam, is open at the circumference. By the revolution of this wheel an immense length of pipe is exhausted in a very short time.

Perhaps a Persian wheel worked by a couple of bullocks would be found to work a thermantidote wheel with sufficient rapidity to exhaust the air from a large barrack; this, however, can only be decided by experiment.

In speaking of a thermantidote wheel, of course an ordinary thermantidote wheel is not intended, but one of proportions scientifically arranged to produce the required effect in the most complete way.

If metal pipes at the roof be objectionable, bundles of hollow bamboo or a light tin pipe suspended from the roof and communicating with the pipe *bd* at B would answer equally well. The Messrs. Chambers (as described in Chambers's Journal) have used tin pipes suspend-

ed from the roof for warming their very extensive printing rooms *with steam*, with great success. Here tin pipes have no steam pressure to bear, and a hole in the soldering here and there would be no great disadvantage.

In buildings to be constructed hereafter, instead of metal or bamboo tubes, let a pipe of masonry run along the top of the walls with openings into the rooms; the pipe being the width of the wall and strengthened by arches where it would have to bear the weight of the beams, the section across the pipe having an area of 6 × 6 inches.

The expense after the first start would be that of working the thermantidote, or of keeping the furnace alight at one end, and of filling the trough K at the other.

The trial of this plan would cost little, and if successful, it would add much to the health of large bodies of men inhabiting one building, as it ensures a constant supply of fresh and cool air without the disadvantages attending our present method of cooling rooms, viz., darkness and the necessity of re-inhaling vitiated air.

The success of the experiment depends, as far as the thermandidote part is concerned, on the quantity of air which can be exhausted by a wheel worked by bullocks—for the rest, *nothing else has been recommended which has not been tried already and found to succeed.*

F. R. De Bude.

Note by Editor.

The plan of ventilation above proposed would no doubt answer for a large room, or even for a moderately sized barrack In a large barrack, however, and especially if the external temperature were very high, I should feel inclined to supplement the furnace arrangement by thermandidotes, blowing in fresh air as proposed in page 109, which would greatly increase the activity of the draught. It would of course be necessary to keep all the doors and windows closed, except such as were not absolutely required for ingress and egress, but this could be done without inconvenience. In the 2nd Volume of the "Aide Memoire," page 406, will be found a drawing and description of Haig's Pneumatic Engine, which is an exhaust thermantidote capable of discharging 6,000 cubic feet of air per hour, and used to ventilate mines or the holds of vessels; but a much more powerful machine would be required for a barrack, where the quantity of foul air to be withdrawn is 2,000 feet per minute.

No. LXVII.

Table of RATES of WORK prevailing in the principal Executive Divisions of the HYDERABAD Circle, Public Works Department, in or about the month of MAY, 1864.

Details.	Period or quantity.	Names of Stations. Secunde-rabad.	Aurunga-bad.	Oomra-wutty.	Aukolah	Remarks.
Rates of Labor.*						* The rates of labor of every description are rising at a very great rate, but more especially able-bodied coolies. Agents from several distant quarters are in the market, it is said that coolies have been offered as much as Rs. 7 per month, but as a rule they are loath to leave their homes.
Stone masons.						
Skilled workman, ...	per day,	..	0 12 0	9 & 10		
Ordinary do., ...	"	..	..	5 to 8		
Bricklayers.						
Mistrie bricklayer, ...	per month,	..	15 0 0	..	..	
Skilled workman, ...	" day,	0 6 0	0 8 0	8 & 9	11 & 12	
Ordinary do., ...	"	4 to 6	0 7 0	5 to 7	0 10 0	
Carpenters.						
Skilled workman, ...	per day,	0 6 0	1 0 0	0 9 0	1 0 0	
Ordinary do., ...	"	4 to 5	0 12 0	0 8 0	8 to 14	
Smiths.						
Mistrie smith, ...	per month,	..	15 0 0	..	..	

Skilled workman, ...	per day,	0 6 0	..	1 0 0	0 15 0
Ordinary do, ...	"	0 5 0	..	0 12 0	..
Painter, ...	"	0 6 6	0 8 0	..	..
Bheestie, ...	"	..	0 5 6	0 10 0	0 8 0
Laborers.					
Beldar, ...	"	..	0 3 2	0 4 8	0 4 0
Mate coolie, ...	"	0 2 9	0 2 0	0 4 0	0 3 0
Coolie,*	"	$1\frac{3}{4}$ to $2\frac{1}{2}$	0 1 6	0 1 9	$1\frac{3}{4}$ & 2
RATES OF MATERIALS.					
Ashlar or cut stone, best quality, at the quarry, ...	per cub. ft	..	0 11 0	0 4 9	..
Stone, best quality, hammer dressed, at the quarry, ...	"	..	..	0 6 6	..
Boulders or undressed stone, at quarry, ...	"	..	..	0 2 6	..
Bricks (best) 9″ × $4\frac{1}{2}$″ × 2″ at kiln,	per 1000	6 0 0	..	..	5 0 0
Tiles, common, native, at kiln, ..	"	2 8 0	3 0 0	..	3 8 0
Lime, best kunkur, at kiln, ..	per 100 mds.	39 0 0	50 0 0	49 0 0	45 0 0
" stone, "	"	54 0 0	not	used.	
Sand, clean sharp river, on work, carried—miles, ...	per 100 mds.	6 8 0	..	..	6 4 0
Timber. †					
Teak, rough, in the log, on work, carried—miles, ...	per cub. ft.	3 0 0	2 0 0	1 8 0	4 0 0
Cartage. ‡					
2-bullock cart, to carry 10 maunds,	per day	0 12 0	0 12 0	1 0 0	0 12 0

† The timber chiefly used in the Secunderabad division is Burmah or Rangoon teak its price is much enhanced from cost of carriage; the other timber is somewhat similar to that at Agra, called Masts, and are bought by the piece, and in consequence of waste, are scarcely deducible to cubic feet The timber at Aukolah comes from Canara, *viâ* Bombay; the high price is owing also to carriage—it was procured for a new jail.

‡ The carts and cattle are very small in this Province, and it is doubtful whether as a rule the load is not considerable less than 10 imperial maunds, but the measures and weights being local, it is difficult to get at a correct result.

* The coolies in this part of the country are chiefly women and children.

Details.	Period or quantity.	Names of Stations. Secunderabad.	Aurungabad.	Oomrawutty.	Aukolah.	Remarks
Rates of Work.						
Roads. *						* There are no metalled roads properly so called in this Province, the usual covering being sand and moorum, generally collected from the beds of rivers and nullahs, the cost is chiefly on cartage, the spreading and rolling being a comparatively small per centage.
Earthwork. †						
Earthwork excavated in light clay or sandy soil, carried if necessary up to 75 feet and deposited in bank, ...	per 1,000 c. ft	3 8 0	5 0 0	8 0 0	6 0 0	† Complaints are being made that even these high rates are not sufficient to induce contractors to undertake the work in portions of the road division, owing to scarcity of labor.
Foundations.						
Excavation of foundations in rock, where no pumping or baling is required, ...	per 100 c. ft.	..	..	14 0 0	..	
Ditto, ditto, in soil, clay, gravel or sand, where no pumping or baling is required, including all planks, shores, struts, &c., ...	”	0 10 0	1 0 0	0 8 0	1 14 0	
Concrete or beton, ...	”	4 12 0	15 0 0	15 0 0	15 0 0	
Stone-work.						
(All set in best mortar.)						
Ashlar, plain, ...	per cub. ft.	..	20 0 0	..	..	
Ditto, voussoirs for arches, ...	”	..	..	51 4 0	..	

Coursed rubble, ...	per 100 c. ft.	..	18 4 0	32 0 0	35 0 0
Rubble, ...	„	..	25 0 0	42 0 0	..
Brick-work.					
Second class brick-work in walls with best bricks, (not dressed) set in best mortar, ditto, ...	„	17 8 0	..	..	25 0 0
Third-class brick-work in walls, with good bricks, set in mud, ditto, ..	„	6 0 0	..	..	..
First-class brick-work in arches, with dressed faces, including centering up to 16 feet span, ...	„	..	..	..	30 0 0
Plastering.					
Best lime plastering for exterior walls ½″, ...	per 100 sup. f.	2 0 0	3 0 0	..	..
White washing, 2 coats, ...	„	0 6 5	0 4 0	..	..
Roofing.					
(Exclusive of timber framing).					
Flat pucka terrace roofing, on one course of flat bricks or tiles, ..	per 100 sup. ft	20 0 0	..	..	..
Tile roofing set in mortar on one layer of flat brick, ...	„	16 0 0	25 0 0	..	..
Flooring. ‡					
Slate floor, laminated, ...	„	18 5 6	..	..	..

‡ The buildings in the Secunderabad division are all being floored with granite, on which the Executive Engineer remarks, "the only class of men who undertake this work are few in number, and although there is no want of granite rock, it is not safe to enter into any contract with them; and a great deal of management is requir-ed to get any work at all out of such an intractable set of people as they are known to be."

Details	Period or quantity.	Names of Stations.				Remarks
		Secunderabad.	Aurungabad.	Oomrawutty.	Aukolah.	
Timber-work.						
Teak timber, wrought and put up in roofs, bridges or centerings, including nails and screws, but exclusive of bolts and straps, ..	per cub. ft.	3 5 0	..	..	..	
Pannelled doors of Saul, Deodar, Teak or Sissoo, ...	per sup. ft.	0 14 0	0 15 0	..	..	
Painting						
Painting wood, with 3 coats, Green, Red or White, ...	per 100 sup. ft	10 0 0	8 0 0	..	..	

MEMO.—The only station in this Province at which masonry works are being carried on is Secunderabad, the other stations given are sub-divisions of roads; the rates therefore except for the station of Secunderabad are not trustworthy as guides, the roads in the province are so extensive and pass through districts so varying in population and from other causes, the Executive Engineers have not yet been able to prepare trustworthy estimates. In many places laborers are very difficult to procure, but carts almost entirely so. In some instances, common hammer-dressed masonry for culverts has cost the enormous sum of Rs. 100 per 100 cubic feet, owing to the distance material had to be carried.

BOLARUM, 23rd August, 1864.

CHAS. NUTTALL,
Deputy Controller and Examiner,
P. Works Accounts, Hyderabad.

No. LXVIII.

RAILWAY SUSPENSION BRIDGES.

On the effect of an Unattached Suspended Iron Girder in checking the undulation of the road, as a heavy Train passes over a Railway Suspension Bridge. BY ARCHDEACON PRATT.

To the Editor of Professional Papers on Indian Engineering.

SIR,—Three years ago Mr. Turnbull, the Chief Engineer of the East India Railway Company, requested me to give an opinion, on theoretical grounds, regarding the effect of a Suspended Iron Girder in checking the undulation as a heavy train passes over a Railway Suspension Bridge. He gave me the data of the bridge he had projected for the Hooghly. A calculation was made and published in London, in the "Philosophical Magazine," for June 1862, and a report of the results was given to Mr. Turnbull.

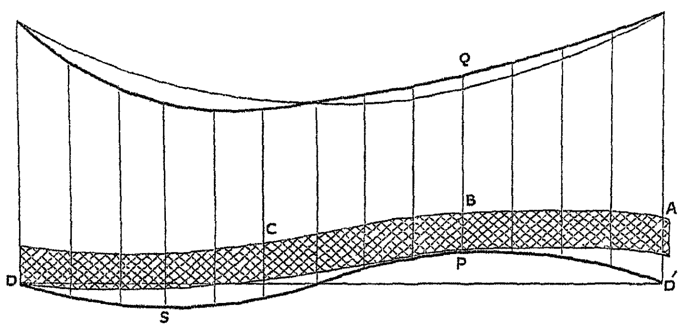
As the subject of a Railway Suspension Bridge across the Hooghly is being revived, it occurs to me that it may not be unacceptable to you if I enter a little more into detail, than I did in the "Philosophical Magazine," in explanation of the process I followed in making the calculation there published. It affords a good illustration of the kind of help that theory can lend to practice.

2. The data of the bridge which Mr. Turnbull proposes to construct are as follows:—

The bridge consists of five spans and two half spans. Each span is 400 feet; the versed sine of the chains at the middle point is 33 feet 4 inches; the weight of the chains, including suspending rods, 200

tons; the weight of the girder and roadway 350 tons: the maximum moving load, when occupying the whole span, 400 tons; the depression of the girder at its middle point, when supported at its two ends, from its own weight alone, 0·7 foot, from the weight of the train 0·9 foot in addition, making 1·6 foot in all.

3. Suppose that on the train coming upon the bridge the roadway is thrown into undulation. The iron-girder will partake of the effect. The undulation, however, can never become so great as is represented in the following diagram, in which the girder is actually separated for



a time from the roadway, except at two points of support D and P. For the enormous weight which would in that case be brought upon the point P would prevent such a rise. More than half the weight of the girder would be thrown upon the suspending rod QP; and the weight of the train could never communicate through the chains an upward tension in the direction PQ capable of sustaining this load. It is clear from this, that the weight of the girder will keep down the undulation, and that in this arrangement of a Suspended Girder, the undulation of the roadway can never exceed the curvature of which the girder alone is susceptible when left free to itself. The girder and roadway (or rather, the loops of the suspending rods in which the girder lies, and which are always in the same level as the roadway) will always remain in contact. It is in this that the great advantage is seen of having the girder *freely* suspended, that is, lying in the loops of the suspending rods *unattached* to them. If the girder were attached all along to the loops and so to the roadway, the effect would be, that when the road is thrown into undulation, a force would be

produced all along the girder, through the points of attachment, which would assist in bending the girder more than the natural flexure into which its own weight alone would bring it. Thus, to refer to the diagram; as the natural flexure of the girder when left to itself is only DP, and of the roadway caused by the train (if there were no girder to keep the undulation down) is DSP, then the curvature of both of them, if they were attached to each other, would lie somewhere between these curves, and would therefore be greater than that of the free girder. But the undulation of the roadway can never, for the reason I have assigned, be greater than that of the girder. Hence the undulation of the roadway is least when the girder is suspended free and unattached. In order, then, to find the degree of undulation of which the roadway is susceptible in this arrangement, we must find the degree of flexure which the girder can undergo.

4. I will take the extreme case of the girder and roadway being thrown into their greatest possible degree of flexure, that is, the girder on the verge of separating from the roadway except at the two points D and P. Take B, immediately over P, make BC = BA. Then the flexure of the girder cannot be greater than that of a free girder of length AC, suspended at its middle point P. It may be less than this, because the undulation may be so far checked as not to give the girder the whole flexure of which it is naturally susceptible. But it cannot be more. Now the flexure of a lattice girder suspended at its two ends, or at its middle point, varies as the square of its length, all other things being the same. If the girder were a solid beam its flexure would vary as the cube of its length: but being a lattice, in which the upper and lower bars sustain the weight by compression and extension, the flexure varies only as the square. Hence the greatest possible flexure of AC is to that of the whole AD (= 0·7 foot) as $AC^2 : AD^2$. And the flexure of CD is to that of the whole as $CD^2 : AC^2$. If then, we can find the position of the point P, where the upward pressure produced by the undulation is the greatest, for every position of the train upon the bridge, we can at once find the greatest flexure of which the girder is susceptible, and therefore the greatest undulation to which the roadway is liable. It is to the solution of this problem that the calculation in the "Philosophical Magazine" is devoted. The line of reasoning I will now explain.

5. I suppose the train to be at rest on the bridge. We have first to find the form into which each chain is forced by the weight of the train. The roadway, train, and chains, are in this calculation considered to be perfectly flexible and devoid of all stiffness. This is taking the most unfavorable case which could possibly occur, as the natural stiffness must produce resistence and friction enough to check a part of the undulation which would arise in a perfectly flexible body. I shall suppose the weight of the roadway and suspending rods to be thrown into the chains so as virtually to increase their uniform thickness; and the same with the train, the weight of which I suppose to be added to the part of the chains immediately over the train, virtually increasing its uniform thickness. Suppose that the virtual thickness of the chains loaded by the train, is β times the virtual thickness of the chains without the train but with only the roadway and rods. Then in the Hooghly bridge $\beta = 200 + 350 + 400$ tons $\div$ $200 + 350$ tons $= \frac{19}{11}$ When the whole bridge is covered by the train the curve of the chains will be the common catenary. When the train is only partly on the bridge each chain will virtually consist of two parts, one β times as thick as the other. The first part of the problem solved in the "Philosophical Magazine," is to find the form in which this compound chain will hang. Each of the two parts of the chain will be uniform and hang in a common catenary; but the two catenaries to which the two parts belong will be different to each other. They will have a common tangent at the point where they meet. The following

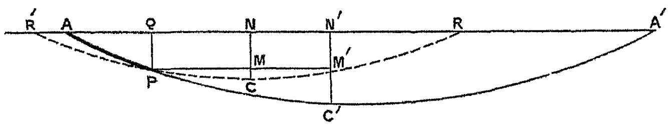


diagram represents the curves. APA′ is the whole chain; AP is the thick part and belongs to the catenary APR: the other part PA′ hangs in the catenary A′PR′; the two catenaries have a common tangent at P; C and C′ are the lowest points of the catenaries.

6. The calculation brings out the following results:—Let C be the length of chain, the weight of which measures the tension at the lowest point of the common catenary in which the chain hangs when the whole bridge is covered by the train or has none on it; c and c' the

lengths of chain which measure the tensions at the lowest points of the catenaries AP, and PA$'$.

Let CN $= k$, C$'$N$'$ $= k'$, AA$'$ $= 2b$, NA $= h$, N$'$A $= h'$, APA$'$ $= 2m$, AP $= t$, the distance the train is on the bridge.

Then

$$\frac{c^2}{C^2} = \tfrac{1}{2}\left(1 - \frac{\beta - 1}{\beta}\left(1 - \frac{t}{2m}\right)^2\right)^3$$

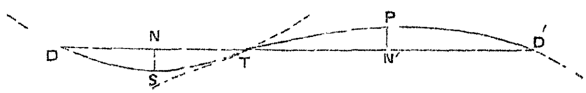
$$+ \frac{\beta - 1}{2}\left(1 - \frac{t}{m} - \frac{\beta - 1}{\beta}\left(1 - \frac{t}{2m}\right)^2\right)^3 + \frac{\beta}{2}\left(1 - \frac{\beta - 1}{\beta}\left(1 - \frac{t^2}{4m^2}\right)\right)^3$$

$$c' = \beta c, \text{ and}$$

$$h = \frac{m^2}{2c}\left(1 - \frac{\beta - 1}{\beta}\left(1 - \frac{t}{2m}\right)^2\right)^2, k = b\left(1 - \frac{\beta - 1}{\beta}\left(1 - \frac{t}{2m}\right)^2\right)$$

$$h' = \frac{\beta m^2}{2c}\left(1 - \frac{\beta - 1}{\beta}\left(1 - \frac{t^2}{4m^2}\right)\right)^2, k' = \beta b\left(1 - \frac{\beta - 1}{\beta}\left(1 - \frac{t^2}{4m^2}\right)\right)$$

7. Having thus found the form into which the chain is distorted for any position of the train on the bridge, the curve into which the roadway is thrown by this distortion has next be calculated. This is done in the "Philosophical Magazine," by comparing the compound catenary into which the chain is now drawn, with the catenary in which it hangs when the train covers the whole road. The vertical spaces between these two curves, at successive points across the bridge, by which the first curve is below or above the second, exactly equal the spaces through which the roadway is depressed or lifted up. The result of the calculation is, that the roadway is drawn into an undulation consisting of a parabolic depression and a parabolic elevation, the two portions of parabolas uniting at a common point of the roadway which is not raised or depressed; and at that point the parabolas touch each other, as in the following diagram—



The calculation makes—

Greatest depression, or NS $= \dfrac{\left(\dfrac{k}{b}\dfrac{C}{c} - 1\right)^2}{\dfrac{C}{c} - 1}\, H.$

Horizontal distance of ditto, or DN $= \dfrac{\dfrac{k}{b}\dfrac{C}{c} - 1}{\dfrac{C}{c} - 1}\, b.$

$$\text{Greatest elevation, or } PN' = \frac{\left(1-\frac{k'}{b}\frac{C}{c'}\right)^2}{1-\frac{C}{c'}} H.$$

$$\text{Horizontal distance of ditto, or } D'N' = \frac{1-\frac{k'}{b}\frac{C}{c'}}{1-\frac{C}{c'}} b.$$

H is the value of h when the whole chain hangs in one catenary, or when $\beta = 1$. If these formulæ be reduced to numbers they lead to the following Table :—

	Distance the train has passed along on the roadway, or t.									
	40 feet	80 feet	120 feet.	160 feet.	200 feet	240 feet.	280 feet	320 feet.	360 feet.	400 feet.
Greatest depression of roadway under the train, *in feet*,	0·64	1·57	2 15	2 24	1 99	1 54	1 01	0·53	0 16	0
Horizontal distance of this *depression*, ...	33	56	73	86	97	105	113	120	127	
Greatest elevation of roadway beyond the train, ...	0·28	0 97	1·73	2 24	2·42	2 25	1·78	1·11	0·39	0
Horizontal distance of this elevation from the left pier,	271	275	279	287	297	309	324	342	367	

8. This Table shows us whereabouts the point P of greatest upward pressure on the girder will be, for different positions of the train on the bridge. We can, therefore, now bring the principle of para. 4 to bear, in order to find the greatest possible amount of flexure that the girder can undergo, and therefore the greatest possible undulation which the roadway can receive. The application of that principle leads to the two following Tables :—

	Distance the train has passed along the roadway.									
	40 feet.	80 feet.	120 feet	160 feet.	200 feet	240 feet.	280 feet.	320 feet.	360 feet.	400 feet.
Distance of the greatest elevation of the roadway from the right-hand pier, *in feet*,	129	125	121	112	103	91	74	58	33	0
Ratio of this to half-length of the roadway, ...	0·64	0·62	0·60	0·56	0·51	0·45	0·37	0·29	0·16	0
Deflection of the girder AC,	0·28	0·27	0·25	0·22	0·18	0·14	0·10	0·06	0·02	0

As the train, therefore, occupies these successive positions, the deflection of the girder at P, upheaved and subjected to its own weight, would be continually diminishing,—beginning at the first position with only 0 28 foot or 3·4 inches, lessening to 0·18 foot or 2·2 inches when the train is half-way across, and becoming 0 when the whole train is on the roadway.

The greatest depression of the roadway and girder will be that corresponding to the deflection of a girder of the length DC. The following Table is constructed as the last was.—

	Distance the train has passed along the roadway.									
	40 feet.	80 feet.	120 feet.	160 feet	200 feet.	240 feet.	280 feet	320 feet.	360 feet.	400 feet.
Distance of greatest depression from the left-hand pier, *in feet*, ...	33	56	73	86	97	105	113	120	127	
Ratio of this to half-length to the roadway, ...	0·16	0·28	0·36	0·43	0·48	0 52	0 56	0·60	0 63	
Deflection of the girder DC,	0·02	0 05	0 09	0 13	0·16	0·19	0·22	0·25	0·28	0·70

9. A few words will be of use to explain these Tables. The chains and rods are supposed to be so adjusted that when no train is on the bridge, or when the whole bridge is covered by the train, the girder lying in the loops of the rods is perfectly horizontal, being sustained all along its length by the loops and having no deflection. When a small portion of the train is on the bridge on the left side, a slight depression underneath the middle of that portion will occur, and P the point of greatest elevation of the roadway will at the same time be slightly to the right of the middle of the bridge. The tendency of this will be to upheave the girder near its middle point and to draw upon, so to speak, its liability to deflection. This amount under no circumstances can exceed 0·7 foot; but in the actual case, as a small portion only of the train will be on the bridge, the force it produces will be small for overcoming friction and stiffness, and the deflection will no doubt be much less than this possible maximum.

The first of these two Tables shows that when the train is 40 feet on the bridge, the greatest deflection of the girder would be only 0·28 foot

or 3·4 inches, on the double hypothesis of perfect flexibility and the girder being just on the verge of separating from the loops. Hence, in the actual case, the deflection will be much less than this. The second Table shows, that when the train has reached the right hand pier within 40 feet, the greatest possible deflection of the depressed portion of the girder is also 0 28 foot or 3 4 inches, which, for the reasons before stated, will be actually much reduced by the resistance of friction and stiffness. As the head of the train has different positions nearer and nearer to the right hand pier, the greatest possible deflection would vary rapidly from 0·28 foot to 0·7 foot, if the depressed portion of the girder were left perfectly free to itself to undergo its natural bending. But this will not be the case. The girder will not be separated from the loops, but will always lie in contact with them, and be partially supported so as not to be left to itself resting at only two points; so much so that when the head of the train is at the right hand pier the whole girder will be perfectly horizontal again, owing to the arrangement of the chains and rods, which I have already mentioned.

10. The result then, is this. The theory shows that the girder and roadway will be most deflected when either a small portion or nearly the whole of the bridge is covered by the train, and then it never could exceed 0·7 foot. But in these two cases the force of derangement brought to play by the weight of the train will be comparatively so small, that practically it will be very much counteracted by the resistance from friction and stiffness in the roadway and joints of the rods and chains, all of which are in the theory supposed to be perfectly flexible, and the actual deflection will be much less than 0·7 foot. Again: the force to overcome friction and stiffness is greatest when the train is half way over the bridge. But the theory shows, that then the deflection of the girder will be least, and will not, even if friction and stiffness be absent, be more than 0·16 or 0·18 foot, that is, about 2 inches, and therefore less than that in the actual case. This result is very satisfactory, and shows the advantage of the arrangement of a suspended and unattached girder.

11. The previous calculations have been made on the hypothesis of the train being at rest in different positions on the bridge.

There are two cases which I will now consider when the train is in

motion: (1) when the curvature of the roadway is continuous, without any sudden change; (2) when there is a slight break in the curvature.

(1). When the train is moving with a velocity v, the curved roadway is subject to additional pressure from centrifugal force: the pressure is increased by this effect beyond the simple weight of the train in the ratio of

$$g + \frac{v^2}{\text{radius of curvature}} : g \text{ (or gravity)}.$$

If h be the depression of the roadway when the train is in motion, k the depression when it is at rest, and $2n$ the length of DC the part depressed, then, taking the curve to be part of a circle,

$$\text{radius of curvature} = \frac{2n^2}{h}, \text{ and } \frac{h}{k} = 1 + \frac{v^2}{2n^2 g}\, h;$$

$$\therefore\ h = \frac{k}{1 - \frac{v^2 k}{2gn^2}}.$$

The value of k varies as n^2, as already stated, and equals 0·7 foot when $n = 200$ feet: also $g = 32$ feet, and $v = 88$ feet for a velocity of 60 miles an hour; hence the denominator of h.

$$= 1 - 0{\cdot}0021 \left(\frac{v}{88}\right)^2,$$

and the increase of h above k is therefore evanescent even for a velocity of 60 miles an hour.

If any part of the rail, from accident or bad structure, is more curved than I have supposed it to be, the radius of curvature of that part will be smaller, and the effect of centrifugal force proportionately greater.

(2). Next suppose that there is at some point of the rail a sudden change in the curvature, and that the tangents to the two parts of the curves at that point make a small angle θ with each other. The effect of this will be, that every time the wheels of the train come to that point an impulse or blow will be given to the roadway. The tendency of this blow will be suddenly to separate the roadway curve (which is the same as the curve in which the lowest points of the suspending rods lie) from the suspended girder, since the girder is not attached to the suspending rods. Thus the blow will bring into sudden action the downward pressure of the girder, which will consequently stifle the

effect of the blow, and not suffer the roadway to be thrown into a greater undulation than the girder itself can assume under its own weight, as already described. No doubt a molecular tremor will run along the roadway, girder, and chain occasioned by the blow, but nothing more.

12. But as it is possible that by friction or accident the girder might get attached, at any rate in some places, to the loops and roadway, I will consider what the effect would be if the girder, instead of lying unattached in the loops of the suspending rods, were attached to the roadway.

I must premise that if M be the mass of the girder, and a vertical blow be given to it at any point between its two ends on which it is supported, so as to cause that point to descend with a velocity u, then $\frac{2}{3}$ Mu is the whole momentum communicated to the beam. For let b' and b'' be the distances of the point of impulse from the left-hand and right-hand piers, $b' + b'' = 2b$; than the velocity communicated to a point at a horizontal distance y to the left or right of the point of impulse will be

$$u\left(1 - \frac{y^2}{b'^2}\right) \text{ or } u\left(1 - \frac{y^2}{b''^2}\right),$$

and therefore the momentum of an elementary section of the girder of width dy, being integrated, will give the momentum of the whole girder

$$= \frac{\mathrm{M}u}{2b}\left\{\int\left(1 - \frac{y^2}{b'^2}\right)dy + \int\left(1 - \frac{y^2}{b''^2}\right)dy\right\}$$

$$= \frac{2}{3}\mathrm{M}u, \text{ the limits being } 0, b', \text{ and } 0, b''.$$

If the train reaches the point of interruption with a velocity v, it moves on beyond that point with the diminished velocity $v \cos \theta$, and it impinges on the roadway with a velocity $v \sin \theta$. The momentum thus communicated to the girder will be Tv sin θ, T being the mass of the train;

$$\therefore \frac{2}{3}\mathrm{M}u = \mathrm{T}v \sin \theta, \therefore u = \frac{12}{7} v \sin \theta.$$

$$\text{since M} : \text{T} = 350 : 400 \text{ tons.}$$

I will now find the depression which a blow communicating a velocity u at the point of interruption will cause: I will take the worst position for the interruption, viz., the middle point. The girder unsupported by a chain will bend, as experiment shows, through 1·6 feet

under its own weight, together with the weight of the maximum load, 400 tons. Let z be the additional depression which would be caused by a pressure P; then

$$P = 750 \frac{z}{1\cdot6} = 470z \text{ tons, nearly,}$$

and the mass of the girder set in motion is equivalent to

$$\tfrac{2}{3} \times 350 \text{ tons} \div g,$$

$$\therefore \frac{d^2z}{dt^2} = -\frac{3g \times 470z}{2 \times 350} = -64z;$$

$$\therefore \left(\frac{dz}{dt}\right)^2 = u^2 - 64z^2.$$

Hence if h be the extent of the vibration caused by the blow, $h = \frac{1}{8}u = \frac{3}{14}\, v \sin\theta$ feet. If v be 88 feet, or the velocity 60 miles an hour, $h = 4$ inches, if $\theta = 1°$, or for a sudden change of 1 in 57 in the gradient of the rail. The depression will be greater or less in proportion to the change in the gradient.

The time in which the girder, on receiving the blow, passes through its depression is $\frac{\pi''}{16} = \frac{1''}{5}$. Each carriage is 25 feet long, and has two pairs of wheels. Hence the interval between successive blows $= \frac{12\cdot5}{88} = \frac{1''}{7}$; and therefore a second blow will occur before the girder has begun to recover itself, and will therefore still further increase the deflection; a third blow and others also will follow before the girder has begun to recover its former position, and these effects being accumulated may become dangerous. The blows will grow feebler and feebler after the first, because each is produced by the impact of only that portion of the train which has not at the moment passed the point of interruption.

If the velocity of the train be 20 miles (the sudden change in the gradient still being 1°), the intervals of the blows will be about $\frac{2''}{5}$ instead of $\frac{1''}{7}$. The result will be, that the second blow will occur just as the girder has sprung back to its original position with a momentum equal to that which the first blow gave to it, but in the upward direction; the second blow will therefore be counteracted by this. The third blow will then have its full effect; but being feebler

than the first, will not produce so great a depression as before; and the successive results will be smaller and smaller.

The calculation in this paragraph is sufficient to show the great importance of the rail over the bridge being entirely free from every impediment or check of every kind, and the advantage of having the girder unattached to the roadway.

J. H. Pratt.

Calcutta, April 1865.

No. LXIX.

CANAL FALLS.

A Suggestion. By Lieut.-Col. Fife, R.E.

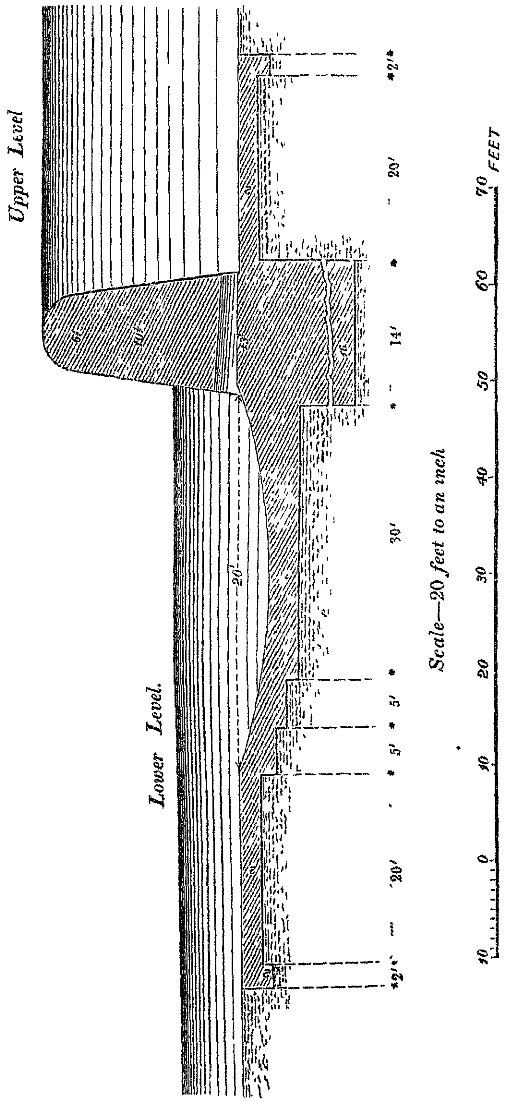
In one of the early Numbers of the Professional Papers, some exceedingly interesting matter appeared on the subject of Canal Falls, and the various expedients which have been employed to prevent the injurious action of the water, but there is still another expedient which might be tried. This is to construct the work like a weir with under-sluices, large enough to pass off the Canal's full supply, without the necessity of allowing a large body of water to pass over the crest of the weir, and tumble upon the masonry with an irregular and destructive action.

In a perpendicular fall, the injurious action of the water is evidently entirely caused from the water striking the masonry, and even where the fall is a sloping or curved one, the action of the water is more severe than it should be. But if the action could be reduced to gliding only, its injuriousness would be reduced to a minimum, and the masonry which is now destroyed, would stand, just for the same reason that the earthen bank of a Canal will stand uninjured where there is a velocity of current of say $2\frac{1}{2}$ feet per second, while precisely the same material is torn away by an eddy with only one-half that velocity.

The weir might have a section like that shown in the sketch below; and to prevent the pond above the weir sinking to too low a level when the Canal is running half supply, some of the sluice openings might be fitted with gates.

By giving the openings a splay, both at top and sides, the eddying of the water below the weir could be reduced till it was not injurious. The masonry used for the face work in the sluices and for the apron immediately below them, should of course be of the very best description. Where

stone is procurable of course that material would be used. Where circumstances necessitate the employment of ordinary brick and lime, the sluice openings would have to be lined with either planking or sheet iron. A portion of the apron immediataly in front of the sluice would require similar protection.



This expedient will not appear new to most Engineers, but as it was not mentioned in the interesting papers referred to, it may be worth while to mention it. It evidently has the merit of concentrating action · of the least injurious kind, viz., the gliding action on a small portion of masonry in the most massive part of the work.

The sketch given is intended only to illustrate the arrangements suggested. The necessary dimensions for the apron and its precise construction must depend on many local circumstances, and Canal Officers accustomed to see the effects of shoots of water at existing falls will no doubt see better than myself what length of apron would be necessary. The total length of about 47 feet suggested itself after the writer had observed the effect

of water shooting from under sluices in a large weir. Where sand forms the bearing stratum, pitching would be necessary at the tail of the apron.

With respect to brick-work for the important parts of Canal falls it may prove economical, from securing greater permanency, to use compressed bricks of a very large size. As an experiment, the writer of this memo. made a brick $1\frac{1}{2}$ feet long 9 inches broad and 6 inches thick, and when the clay was still in a tough state it was put into a strong mould and subjected to very considerable pressure from above by means of a lever. The brick so made came out of the kiln without any flaw, and from its weight and hardness was more like a stone than a brick. The mould, &c., was a very primitive one, and would not have stood much work; but iron moulds with a screw press above might be easily made, and would last for a very long time. Clay cannot be compressed with much advantage when it is in a soft state, as it expands again when the pressure is withdrawn. To make a very solid brick, therefore, the shaping mould and pressing mould must be distinct. The pressing mould should of course be a little smaller than the shaping one, and after the brick has dried a little and shrunk, it should be put into the pressing mould.

J. G. FIFE.

NOTE BY EDITOR.

One of the Falls on the Baree Doab Canal has been built on the same *principle* as that above proposed, through differing in detail. It was I believe designed by Captain Crofton, and has been found to answer fairly. The objection to it, I understand, was the severe action of the water on the under sluices (which might, however, be prevented by the proposed method of lining them with sheet iron) and the difficulty of getting at the sluices, if anything goes wrong, without stopping the canal supply. In the open falls, one bay at a time can be laid dry and repairs executed, without stopping the supply over the rest of the fall.

The principle of the Rajbuha Falls, advocated by Captain Thomason, in his report on the Terrai (Professional Papers, vol. i. page 428), is also somewhat similar to the proposed method.

No. LXX.

ON THE EXPANSION OF MASONRY BY HEAT.

Adapted from an article in Les Annales des Ponts et Chausseès, for March and April, 1863, *entitled "Experiences sur la Dilation des Maconneries.* PAR M. BOUNCEAU, *Ingenieur en Chef des Ponts et Chausseès."*

A FEW unimportant fissures which appeared during the winter of 1859-60, in certain parts of the works at Havre, when they were nearly completed, caused great uneasiness to the French Engineers.

At first they were attributed to unequal settlement of the foundation.

But on close observation it was found:—

1*st.* That the largest cracks occurred in a wall uncovered on both sides, and in which unequal settlement could not possibly have taken place.

2*nd.* That the temperature of the water in winter averged about 54° Fah.

3*rd.* In the summer of 1859, the fissures almost entirely disappeared; the temperature then varied between 77° and 88° Fah.

It was then conjectured that the fissures were occasioned by contraction caused by decrease of temperature. In order to test this hypothesis the simplest mode of proceeding was evidently:—

1*st.* To compare the width of the cracks with the lengths of the masses of masonry in which they occurred: masses which from their relative weights would crack rather than contract.

2*nd.* To apply the coefficient of expansion for masonry to them.

But as no such coefficients could be found in scientific works, the following experiments were made to supply the omission.

The experiments were made on rectangular bars of masonry from 5 feet 6 inches to 7 feet 9 inches long,* immersed in water, the temperature of which was raised from 50° to 203° Fah.

The bar rested on rollers at the bottom of a tank, and butted at each extremity against the lower end of a vertical lever or rod. This lever was connected with a horizontal axle supported at each extremity; above and to the axle a telescope was fixed. The two supports were separated from the walls of the furnace, and the axles as well as the telescopes were wrapped in cotton wool, so as to guard against the effects of radiated heat (see *Plate*).

A telescope having been placed at each extremity, when the block expanded each telescope became deflected, discribing an arc on a scale† placed at a distance of about 100 metres (328 08 feet.) This gave a very appreciable length of arc for a very small elongation in the bar of masonry.

In order to test the working of the instrument, experiments were made onbars of metal, the co-efficients for which were known; the result proved most satisfactory.

Each experiment was tried twice, and the results were rejected if both did not agree.

The arc described by the telescope per millemetre of expansion was determined each time by direct measurement. In short every possible precaution was taken to ensure exactness.

The experiments were made on ten different substances which happened to be at hand, and most commonly used in the work, viz. .—

1*st*, Portland cement, properly tempered, and allowed to set under water; 2*nd*, Mortar of Portland cement, containing two parts of siliceous sand to one of cement; 3*rd*, Brick-work, (set in the mortar above-mentioned,) the bricks laid all stretchers; 4*th*, The same Brick-work, but the bricks laid all headers; 5*th*, Bèton, composed of mortar as above, and round siliceous pebbles; 6*th*, Lime-stone, from Ranville quarry; 7*th*, Lime-stone, from Maladiene à Caen; 8*th*, Granite; 9*th*, Marble; 10*th*, Gypsum.

Knowing the co-efficients for mortar and stone, that for ashlar may be deduced.

The experiments are contained in the subjoined table.

* The cross section varied—it was generally a square, the side of which measured 7 or 8 inches.

† The arc and tangent are assumed identical.

Table of Co-efficients of the Expansion or Contraction of Materials employed in Masonry.

No. of Experiments.	Nature of Materials.	Length l.	Length of arc per millim. of expansion. A	T	Length of arc observed. A′	T′	Quotient of $\frac{A'}{A} = d$.	$\frac{T'}{T} = d_1$	$d + d_1$.	Temperature Cent. Lowest—t	Highest—t_1.	Difference $t - t_1$.	$K = \frac{d + d_1}{(t - t_1) l}$.	Mean expansion per metre per degree—Cent.	Expansion per foot per degree Fahrenheit.
		Metres.	Metres	Metres	Metres	Metres.	Millimetres	Millimetres	Millimetres	Dgs	Dgs	Dgs.			
1	Bar of Pure Portland cement,	2·00	0·158	0·149	+ 0·165	+ 0·120	+ 1·044	+ 0·806	1·850	12	97	85	0·0000109	0·00001070	0·0000594
2	Ditto,	2·00	0·157	0·149	+ 0·125	+ 0·111	+ 0·791	+ ·744	1·535	22	95	73	0·0000105		
1	Mortar of Portland cement, ..	2·00	0·157	0·149	+ 0·205	+ 0·060	+ 1·305	+ 0·403	1·708	17	94	77	0·0000110	0·00001180	0·0000655
2	Ditto, ..	2·00	0·157	0·149	+ 0·174	+ 0·102	+ 1·108	+ 0·684	1·792	18	94	76	0·0000126		
1	Brick-work (all stretchers),	1·69	0·158	0·168	+ 0·125	+ 0·336	+ 0·791	+ 2·000	1·209	5	90	85	0·0000084	0·00000885	0·0000495
2	Ditto, ..	1·69	0·158	0·168	+ 0·072	+ 0·153	− 0·455	+ 0·910	1·365	8	95	87	0·0000093		
1	Brick-work (all headers,) ..	2·00	0·158	0·149	+ 0·16	+ 0·25	+ 1·012	+ 1·678	0·666	22	95	73	0·0000456	0·00000463	0·0000255
2	Ditto, ..	2·00	0·158	0·149	+ 0·055	+ 0·165	− 0·348	+ 1·107	0·759	14	95	81	0·0000469		
1	Concrete in Portland cement,	2·40	0·157	0·162	+ 0·460	+ 0·0224	+ 2·93	− 0·15	2·78	13	97	84	0·0000137	0·00001430	0·0000794
2	Ditto,	2·40	0·157	0·162	+ 0·225	+ 0·253	+ 1·43	+ 1·56	2·99	12	96	84	0·0000148		
1	Stone from Ranville, ...	2·00	0·161	0·149	+ 0·092	+ 0·10	+ 0·572	+ 0·671	1·243	10	90	80	0·0000078	0·00000750	0·0000417
2	Ditto, ...	2·00	0·161	0·149	+ 0·075	+ 0·072	+ 0·466	− 0·49	0·956	26	91	65	0·0000072		
1	Stone from Maladiene, ..	2·00	0·158	0·149	+ 0·405	+ 0·182	+ 2·56	+ 1·22	1·34	18	92	74	0·0000905	0·00000880	0·0000495
2	Ditto, .	2·00	0·158	0·149	+ 0·132	+ 0·063	+ 0·835	+ 0·423	1·258	16	88	72	0·0000873		
1	Granite, ...	2·00	0·158	0·168	+ 0·070	+ 0·140	+ 0·443	+ 0·833	1·276	14	95	81	0·0000079	0·00000795	0·0000439
2	Ditto, ...	2·00	0·158	0·168	+ 0·110	+ 0·098	+ 0·696	+ 0·590	1·286	15	95	80	0·0000080		
1	Marble, ...	1·868	0·157	0·149	+ 0·050	+ 0·645	+ 0·318	+ 0·433	0·757	19	94	75	0·0000054	0·00000545	0·0000299
2	Ditto, ...	1·868	0·157	0·149	+ 0·072	+ 0·055	+ 0·459	+ 0·369	0·828	14	95	81	0·0000055		
1	Gypsum, ...	2·00	0·158	0·157	+ 0·440	+ 0·020	+ 2·78	+ 0·127	2·907	9	93	84	0·0000173	0·00001665	0·0000922
2	Ditto, ...	2·00	0·158	0·157	+ 0·200	+ 0·000	+ 1·266	+ 0·000	1·266	40	80	40	0·0000016		

The letters A and F represent the two telescopes of the apparatus, K is the co-efficient of dilation.

From this it appears that the contraction or expansion per degree Fah. per foot in length is—

1.	For pure Portland cement, - - - - -	·00000594
2.	Mortar of Portland cement, - - - - -	·00000655
3.	Brick-work in the same mortar, the bricks laid all stretchers, - - - - - - - - -	·00000495
4.	The same Brick-work, the bricks laid all headers, -	·00000255
5.	Bèton of mortar, as above, and pebbles, - - -	·00000794
6	Lime-stone, - - - - - - - -	·00000417
7.	Another specimen, - - - - - - -	·00000495
8.	Granite, - - - - - - -	00000439
9.	Marble, - - - - - - - -	00000299
10.	Gypsum, - - - - - - - -	·00000922

These co-efficients, although they appear infinitely small, sometimes produce very apparent and not altogether harmless effects in works of large dimensions.

Suppose for instance an invert of Bèton in Portland cement, the thickness of which at the crown is 10 feet and span 100 feet, carrying at the springing heavy abutments of such a weight that the force of cohesion on a bed of bèton 10 feet thick is not sufficient to draw the two abutments together.

If the temperature is suddenly diminished by 20° Fah., and the crack be supposed to occur at the crown, its width will be—

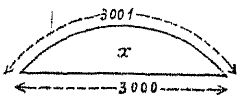
$$100' \times 20^\circ \times \cdot 00000794 = \cdot 01588$$
$$- \cdot 01588 \times 12'' = \cdot 19056 = \tfrac{1}{5}'' \text{ nearly.}$$

Again take the case of a wall 3000 feet long, and suppose the temperature to change suddenly from 80° to 40° Fah., it will contract nearly a foot.

If the fissure were to become filled up with mortar or rubbish, and if the extremities of the wall are immovably fixed, on the temperature again being raised the wall will become deflected some $33\frac{1}{2}$ feet.*

Practically perhaps it would never amount to so much, because a long wall is composed of a number of relatively very small bricks, often imperfectly bedded in cement.

$$* \tfrac{1}{3}\left(8\sqrt{1500^2 + x^2} - 3000\right) = 3001$$
$$x = 33\tfrac{1}{2},$$



However it would seem advisable to leave small openings of a few inches at intervals in very long walls.

Referring to the experiments it appears that gypsum expands most and marble least.

Bèton expands more than brick-work; it is $3\frac{1}{2}$ times greater when the bricks are laid as stretchers, and three times greater when the bricks are laid as headers.

A. HUGHES, *Assistant Engineer.*

THE GANGES CANAL CONTROVERSY.

THERE are probably few readers of these Papers who have not heard some rumours of the controversy which has now for some time been carried on regarding the alleged defects of the Ganges Canal, which has been thought important enough to find a prominent place in the "Times," and which has been the theme of sundry articles in the Indian papers. The points on which the discussion turns are, however, so purely professional, that I believe it will be of use to Engineers interested in the question, and who have not had the opportunity of reading the pamphlets printed on both sides, to put before them in a brief form an abstract of the questions in dispute.

The general history of the Ganges Canal may be shortly told. Designed by Sir Proby Cautley, and chiefly executed under that officer's superintendence, it was formally opened in 1854; and the various subsidiary channels required for its full development as a great work of irrigation have been since rapidly pushed to completion. Intended primarily (if not entirely) to water the thirsty lands between the rivers Ganges and Jumna, and to secure the population from the horrors of famine; its revenue, arising almost entirely from water-rent, has risen steadily from Rs. 8,571 in 1855, to Rs. 7,05,800 in 1863, while the value of the crops depending on the Canal were reckoned in the latter year at $1\frac{1}{4}$ millions sterling.

But satisfactory as this was, it began to be rumoured not very long ago that many of the important masonry works of the Canal were in a dangerous state. In 1862 it was entirely closed for six

months to effect repairs, and though this was a solitary instance, it was known that the cost of ordinary annual repairs was very heavy, while it was reported that the quantity of water carried by the Canal was considerably under what had been originally intended.

At the beginning of 1864, Major-General Sir Arthur Cotton, of the Madras Engineers, whose name was widely known in connexion with the great works of Irrigation in his presidency, and for his able advocacy of the importance of Indian Public Works generally, (including sundry heterodox opinions touching Railways) paid a short visit to the head of the Canal, and a few months afterwards drew up a report, said to be confidential and for the information of the East Indian Irrigation Company alone, who had contemplated the possibility of purchasing the Canal from Government, but which report quickly became to a certain extent, public.

In this pamphlet, Sir Arthur roundly asserted that the design of the Canal was faulty and its execution defective, accusing its projector of no less than *five* great mistakes and *fourteen* minor ones.

To this pamphlet Sir Proby Cautley (who had resigned charge of the Canal soon after its opening, and is now in the Indian Council) quickly published a reply. The five great mistakes he denied *in toto*, and of the fourteen minor ones pleaded guilty to three only, of which two were of no great consequence, but acknowledging frankly that the third (the excessive slope of bed) was a very serious error; and was only justified by the fact that he had had no previous guides to follow, and that its remedy was obvious, and though expensive, involved no difficulty; nor was the expense of the work *in itself* greater than what would have been incurred had it been executed at first. It will be convenient to give the charges, and the replies opposite to them in as brief a form as possible.

Objections.	*Replies.*
1st. The head of the Canal is placed too high up, above a tract which has a very great and inconvenient fall, and in which there is a very heavy drainage from the Sub-Himalayas, across which the Canal has to be carried.	It was necessary, in order to gain command of level and to have a permanent head not liable to alteration.

2nd. The *whole* Canal has been cut so as to carry the water *below* the level of the surface, entailing a vast unnecessary excavation, and keeping the water below the level at which it is required for irrigation.	Necessary for sanitary purposes, and to prevent formation of swamps. The water level is quite high enough for irrigation.
3rd. The whole of the masonry works are of brick, while the most suitable stone for hydraulic works is procurable in the Sub-Himalayas.	The stone in general was not suitable for hydraulic works, and to procure suitable stone the expense would have been enormous, as until the Canal was opened, there was no means of carriage.
4th. The *whole* of the water is admitted at the head, so that some of it is *conveyed three hundred and fifty miles* to the land it irrigates, while it might have been obtained at a sufficient level at a distance of say 50 or 100 miles.	This implies an entirely different design, which the levels and nature of the river would not admit of. This is more fully answered further on.
5th. There is no *permanent* dam across the river at the head of the Canal, so as to *secure* the supply of water, but *temporary* works are thrown up after every monsoon, which are liable to be swept away, and have been swept away, at the very time when they are most wanted.	A permanent dam was always contemplated and will hereafter be made; but it would have been rash to have made it at first, until the effects of the temporary dams on such a river as the Ganges had been observed.

Besides these *fundamental* mistakes there are the following *minor* ones:—

1st. All the weirs are made of a length corresponding with the full breadth of the Canal, while they need not, and ought not, to have been more than one-third of that length, entailing a more than double expense in their construction.	The weirs or falls are divided into chambers, and with the present arrangement, any accident in one chamber does not necessitate a stoppage of the supply. If their length were diminished this could not be done.
2nd. These weirs are placed *in the direct line* of the Canal, while the navigation line and the locks are placed *out of the direct line,* thus compelling *the whole of the traffic* to go round, instead of the irrigation water.	The Canal is primarily for Irrigation, not for Navigation.

3*rd*. The whole Canal has *too great a fall in its bed*, from 15 inches to 12 inches per mile, which, with a depth of 10 feet, which it was intended to have, gives a current of $2\frac{1}{2}$ or $2\frac{3}{4}$ miles an hour, which is too much both for the bed and banks of the Canal, and also for effective navigation.	Granted; it is the one great mistake that has been made; but it can be rectified without any departure from the general design.
4*th*. The Canal has been terminated at Cawnpore instead of being carried on 120 miles to Allahabad, where the Jumna and Ganges unite, and the river navigation begins to be effective throughout the year.	My project was for irrigation above Cawnpore, not for navigation below Cawnpore.
5*th*. The slope of the Canal is continued to the end at Cawnpore, so that to keep the navigation open there must be a large body of water constantly flowing to waste into the river.	Essential for a Canal of irrigation; the water must be taken down to the furthest point where it is wanted.
6*th*. The bridges are so low as to prevent a fully loaded boat passing under them.	Granted, for the bridges in the lower part of the line; this can be rectified.
7*th*. The towing-paths are not carried through the arches of the bridges, so that the line has to be thrown off at every bridge, that is, at every 3 miles.	Granted; it should be rectified; but the Canal was primarily for Irrigation.
8*th*. The lock channels have such sharp curves that boats of the length of the locks cannot pass through them.	I do not agree.
9*th*. No arrangement has been made for the disposal of the silt.	It is carried off into the river by the escapes and termini.
10*th*. There are no *connecting navigation lines* between the different main branches, so that boats can only get *across* the tract by going all the way up to the point where the branch and the main line divide.	It is a Canal for Irrigation. Such connecting lines can easily be made when required.
11*th*. The Solani aqueduct is made *of the full breadth of the Canal above,*	Length and breadth were fixed after full consideration of the waterway re-

and of *the full length of the breadth of the river below*, whereas it might have been made of *one third of the breadth of the Canal*, and its length of about *one-half of the breadth of the river*, reducing its cost to perhaps one-quarter or one-fifth of what it has been.	quired by the Canal and River. The *breadth* given allows half the aqueduct to be laid dry for repairs without stopping the Canal, and subsequent floods show that the *length* is not at all too great to allow a proper waterway for the River.
12th. The breadth of the Canal at the lower end is much too small for a large traffic, such as there would be if the navigation were in an effective state.	It is an Irrigation Canal.
13th. The slopes of the sides of the Canal are much too steep.	I am of a different opinion.
14th. There is no communication between the Canal and the river at Cawnpore, for though there are double locks the gates of the lower one were not in repair.	Not worth a reply.

On this defence appearing, Sir A. Cotton published a second pamphlet, re-iterating his charges, but dwelling more particularly on the point he had previously put forward, viz., the wrong position of the head of the Canal: and to this point the discussion was thenceforward practically narrowed. Sir Proby Cautley published a dissertation upon the heads of the Ganges and Jumna Canals, entering fully into the peculiar physical aspect of the country and the reasons for his choice of the present head; and in reply to this, a third pamphlet was put forth by his opponent, re-iterating his previous opinion.

Here the discussion virtually rests as far as the two pamphleteers are concerned. The "Times," however, in a long article has reviewed the whole discussion, and summed up dead against Sir Proby Cautley, and the Indian Press has virtually adopted the same side. It is greatly to be deprecated that such hasty opinions should be pronounced by non-professional journals on questions which are essentially technical and professional, and which require much fuller discussion before any proper opinion can be formed, than is likely to be found in the columns of a newspaper.

In order fully to understand the main point at issue, it is necessary to give a brief sketch of the system of irrigation as pursued in India, which may at least be interesting to English readers.

There are two distinct systems in use in Northern and Southern India, which may be called the Bengal and Madras systems, respectively.

The Madras system has been confined to the Deltas of the great rivers,—the Kistnah, Godavery, &c.,—and consists in throwing a Weir (or *Anicut,* as it is locally termed) across the bed of the river to raise the surface level of the water, which is then conducted by Canals whose mouths are just above the dam to the lands requiring it. In low alluvial tracts, especially where the river bed has been raised by successive deposits of silt above the level of the country, it is evident that such a system has great facilities. Moreover, the slope of the ground is gentle; the irrigation channels can easily be made navigable; no expensive masonry works are required beyond the dam at the head, and as soon as the head works are completed, the Canals can be opened and begin to pay.

But the country in Northern India is very different from this: here we have a high table land (the *Bangur*) through which the river runs in a deep trough, with steep earthen banks, often 100 feet high, bounding the narrow *Khadir* or low valley of the river. To get the water on to this high land, we must go to a point high up on the river's course, close to where it leaves the hills, whence it can be conducted without excessive depth of digging along the watershed of the country. And as we have to deal with the river in the upper portion of its course, instead of the lower portion near its mouth, numerous expensive masonry works are required to control the excess of slope and to cross the numerous lines of drainage. So that not until all these are completed can the Canal begin to pay, and the cost is mile for mile very much higher than in Madras.

In the above description I have to some extent "begged the question," as, those who contend that the Madras system is applicable in Upper India, deny the necessity of going so high up for a

head, and would have a weir of sufficient height lower down. It is obvious that the question is one of expense.

In the annexed map the line of the present Canal is laid down. It will be seen that it leaves the Ganges at the point where that river finally leaves the hills. For nineteen miles it is then carried by a somewhat circuitous route across four great drainage lines, involving deep cutting, high embanking, and masonry works of an elaborate and expensive nature, until at Roorkee, it finally arrives on the table land of the Doab, and is carried on the water-shed of the country in its further course downwards. There is very little irrigation above Roorkee, so that the great cost of the first nineteen miles has been incurred simply to bring the Canal to its field of usefulness at and below Roorkee. Rajbuhas (minor water-courses) distribute its waters on both sides all the way down, the supply being thus gradually expended, and the size of the channel proportionally contracted.

Now, Sir A. Cotton asserted that, by making a short cut on or near the lines AB or AC, the water might be brought on to the land where irrigation begins, by a much shorter route, the surface level of the water in the river being raised by a weir. He further set forth that, to employ a series of such dams and short cuts from the river at various convenient points, would be far less expensive than bringing the whole of the water all the way from Hurdwar as at present, by which a very capacious channel was required to carry it some hundreds of miles, before it was used for irrigation in the lower part of the Doab. Not to mention that in the former case a portion only of the river water could be thus utilized, while in the latter there was no Engineering impossibility in using up the whole, for whatever was passed over the upper dams would be utilized by those lower down; while the main channel and works could be very much reduced in size.

There are two questions involved in the alternative projects. 1*st*, Can permanent weirs be erected and maintained across rivers like the Ganges, with sandy beds and low banks, especially where the fall is above 3 feet a mile? 2*nd*, Do the levels of the country admit

of channels being excavated from the sites of such weirs, at a reasonable expense, so as to take the water on to the high table land?

As to the first question, Sir Proby Cautley is evidently sceptical. Sir Arthur Cotton says he has made many weirs, but his opponent replies that he has not made them under the required conditions. In one of his late pamphlets, however, General Cotton adduces the case of the Pallaur Anicut, which seems quite conclusive as to the feasibility of such weirs. It is to be observed, however, that for such works an abundant supply of stone near at hand seems essential, a condition only to be met with here and there on Upper Indian rivers, and of which Sir Proby Cautley denies the existence in the present case.

The second question has been investigated lately by the experienced officer specially deputed to Report on the defects of the Canal.* A short cut, such as AB, is out of the question, the top of the high bank forming the boundary of the valley, being 100 feet above the bed of the river. If the line were carried *straight* to the nearest point on the high land to which the levels would admit of the water being conveyed, the great depth of the necessary excavation being far below spring water level, with a sub-soil of pure sand, would involve an expense that puts the project entirely out of the question. If the line were carried by a more circuitous route (such as AC) under the high bank, so as gradually to gain the necessary level without such deep cutting, the cost of the necessary drainage works would equally render this course unadvisable, while in either case the point at which the channel of supply would come out on the watershed, would necessarily involve the abandonment of 70 lineal miles of irrigation above, as may be seen on reference to the plan, (Roorkee to Newarree, 70 miles).

The measures to be adopted for correcting the defects of this noble work are in the opinion of the Canal Officers on the spot, simple enough, as the defects are sufficiently obvious. As the excessive slope has been the cause of all the mischief, so it will be remedied by the introduction of a sufficient number of additional falls, while

* Captain Crofton, R.E.

the diminution of the slope will necessitate some widening of the bed to carry the same amount of water. This is the real work that has to be done, and it contemplates no departure from the original design, the only difficulty being the necessary closure of the Canal, for perhaps the year which will be occupied in their execution. Unfortunate as is this necessity, it is unavoidable, but when re-opened, the Canal will carry its full supply without damage to the works, and with increased facilities for Navigation as well as Irrigation.

I have attempted to set the leading points of this Controversy fairly before the reader; it would be presumptuous in me to give any opinion on the points at issue further than as they involve questions of fact. Had one Engineer been well acquainted with the Madras works when he drew up his design, he would doubtless at least have anticipated most of these objections now made to it, and might have borrowed some hints from Sir A. Cotton and his disciples. Had the other Engineer more fully mastered the data on which his opponent had to work, and seen how much they differed from those with which *he* was familiar, he would probably have modified many of his conclusions. Indian Engineering owes too much to either to do otherwise then regret that professional difference of opinion should have to any extent tended towards personal animosity.

J. G. M.

No. LXXI.

SEALDAH RAILWAY STATION.

Designed and Constructed by Walter Granville, Esq., C.E.

This Station, which is the Calcutta Terminus of the Eastern Bengal Railway, is situated at Sealdah, just outside the famous ancient entrenchment called the Maharatta ditch. The general appearance of the building is very imposing; and reflects great credit on the taste and practical skill of the architect, who designed and superintended personally all the stations throughout the line.

The building is in an Italian style of oriental architecture, and is on a very extensive scale. The two platforms are each above a thousand feet in length, and 27 feet wide. Three light wrought-iron roofs, each 615 feet in length, cover eight lines of rails. These roofs are painted internally light-blue and white, and produce a very pretty effect. The span of each roof is about 53 feet.

The office accommodation for the Executive Staff is very complete, and the waiting Hall is of the following large dimensions, viz., length, 200 feet; width, 40 feet; height, 40 feet. The roofs over all the offices are flat and formed of wrought-iron girders and brick arches, which have a span of 13 feet; the bricks are 6 inches deep. The upper parts of the roofs are covered with the ordinary *khoa* roofing, composed of broken brick, mixed with Sylhet lime, and well beaten in the usual way.

The method by which the great Waiting Hall is lighted and ventilated is original. The chief light is obtained from a considerable elevation immediately above a lower corridor. It is admitted firstly through a series of arches pierced in the outer and inner walls of an upper arcade, which is

built over the lower corridor. This arrangement obviates the necessity of using windows of any kind, since, during the rainy season, the water falls only in the upper arcade; but in cases of violent storms, when the rain beats at a very acute angle, "purdahs" or canvas screens are provided, which can be let down at pleasure.

Owing to numerous large and deep water tanks that had been excavated, very many years past, on the site of this station, the foundations of the buildings were unprecedentedly extensive and difficult of execution. In several places they are as much as 45 feet below the ground floor level, and some of the walls are from 8 to 10 feet thick. The water had to be pumped out by steam-power, without intermission by day or night, before immense masses of concrete could be thrown down in the trenches, which in some instances had to be encased with sheet piling, owing to the spongy nature of the ground.—(*From the Eastern Bengal Railway Hand-book*).

No. LXXII.

THE SUTLEJ CANAL.

(2nd Article.)

Project for an Irrigation Canal from the River Sutlej; abridged from a Report drawn up under orders of the Government of India.
By Capt. James Crofton, R.E.

Distribution of Water Supply.—(*See Map*, p. 146.)

The general directions for two of the branch canals for the irrigation of the Puttiala territory are clearly defined by the watersheds on either side of the Sirhind Nullah; the narrow strip of land lying between the Choa and Puttiala Nullas it does not appear necessary to provide with a branch canal when the supply of water is so limited, nor do the Puttiala authorities apparently consider it of importance. The Nirwanah district, lying on the left bank of the Cuggur, below Khythul, was the part of the territory particularly pointed out as being in urgent need of irrigation; the third series of longitudinal levels was accordingly taken on a line on which it seemed possible, from the general slope of the country and the levels obtained by cross sectioning, to carry a line of canal which would deliver the water at the surface on the ridge between the Cuggur and Chittung in that locality. This involves crossing the Puttiala Nullah, and the Cuggur and Sursoottee rivers; the result of that levelling however, shows clearly, I think, that though we might cross the Puttiala Nullah considerably further to the southward, it will still be necessary to cross the Cuggur and Sursoottee separately, while by thus altering the Puttialla Nullah crossing, we lose the opportunity of irrigating a large portion of land between that Nullah and the Cuggur; I have, therefore, for the purpose of this estimate, projected the third branch in the general direction of that line of levels.

I have before alluded to the circumstance of the direction of the drainage

from the left bank of the Seesooan, and eastward as far as the town of Khurr, being south-westerly towards the Sirhind Nullah; to reach the watershed to the east of that Nullah, it is therefore necessary to cross all the country drainage as far down as the village of Bhayr, about two miles north-east of Sirhind, where we first meet the watershed: the cross section from Sirhind to Machewarah showed the watershed to the westward to lie close to the Kotluh Nullah The neighbourhood of Surranah therefore seemed the most suitable site for the head of the Kotluh branch, the first reach of the line being in such a direction, that the canal embankment would easily divert any small amount of drainage, which might cross from the westward into the heads of the Kotluh Nullah. On the left bank of the central line, from the branch head down to the village of Bhayr, the high spoil banks will answer the similar purpose of diverting the surface drainage into the heads of the Puttiala Nullah; the Nullah passing Khurr, I have before stated, loses its defined section near the village of Kulour, and at the point on the canal line where its flood waters are said to cross, there is nothing but a slight depression in the ground, which the level fails to detect, occupied by rice fields, and some very sandy ground adjoining, to mark the presence of water at some time of the year.

In addition to these for Puttiala, a fourth branch can be taken off from the main channel above Surranah, or perhaps from the Kotluh branch near the town of Budlah, for the irrigation of British territory towards Loodiana, and the districts to the south-west on the left bank of the Sutlej, towards Ubohur in Bhuttiana. The ground not having been examined, no detailed estimate can at present be submitted, but there is no doubt of its practicability, from the known levels of the country near its head and the general direction of the slope of the country; from Captain Dyas's levels I calculate that a channel with the same declivity as the upper portion of the Kotluh branch would deliver the water at the level of the ground surface some distance above Douraha ke Seraee on the Trunk Road.

Without entering into abstruse calculations as to the exact quantity of water required to irrigate a given area, and the amount of loss by evaporation and absorption, for which there are at present no certain data, we may, I think, safely follow the method adopted by Sir P. T. Cautley, of estimating the total quantity required for each branch by an average expenditure per mile of irrigating channel, obtained from similar works in these provinces. He has calculated this at a maximum of 8 cubic feet per second,

DISTRIBUTION OF WATER.

Localities.		Position in five thousands.		Length in five thousands			Discharge, cubic feet per second.				Remarks
		From	To	Total.	Non Irrigating	Irrigating	Allowance per 5000.	Expenditure	Required capacity.	Actual capacity.	
CENTRAL LINE.	Heads to Surranah Branch Head,	...	29·32	29·32	29·32	...	...	...	3500	3641	
	Surranah to Nirwanah Branch Head,	29 32	50	20 68	16 98	3 70	6 63	24·53	1186 63	1204	Including extra for prolongation
	Below Nirwanah Branch Head,	50	120	70	...	70	6 63	464·10	464 10	464 00	
KOTLUH BRANCH, ...		...	101	101	15	86	6·63	570·18	835	853	Including prolongation.
NIRWANAH BRANCH, ...		...	77	77	5	72	5·68	408·96	698	691	Including prolongation.

per mile, from data* obtained on the Jumna Canals. Now, considering the improvements which have taken place since then, and are still in progress, in the economical distribution of water, I believe we may safely reduce this allowance. In the following calculations I have arbitrarily assumed 7 cubic feet per second, per mile, (or 6 63 cubic feet per five thousand,) as a maximum, and for the Nirwanah branch this has been further reduced to 6 cubic feet per second, per mile, (or 5·68 cubic feet per five thousand,) the land adjoining the upper portion of that line not requiring canal irrigation so urgently as other districts, and a large proportion of the country lower down being irrigable from the waters of the Cuggur and Sursoottee.

From these data the accompanying table has been compiled, showing the total lengths of channels now estimated for, with the discharges required at each branch head. From the longitudinal section of the channels it will be apparent that there can be no surface irrigation on either of the lines from the Surranah branch head down nearly to the Grand Trunk Road. Below the points to which the present estimate extends, the Nirwanah line can be extended to a length of 51 five thousands; eleven of these in Puttiala, forty in the British districts of Hissar; the Kotluh line, 10 five thousands in Puttiala, thirty in Bhuttiana; we have then the required discharges on each line, as follows:—

Nirwanah branch,	$(72 + 51 =)$	$123 \times 5\ 68 = 698\ 64$	c. ft. per sec.
Kotluh „	$(86 + 40 =)$	$126 \times 6\ 63 = 835{\cdot}38$	„
Central line, ...		$74 \times 6\ 63 = 490\ 62$	„
	Total,	2024 64	

and assuming 3,000 cubic feet per second, to be the maximum supply available throughout the year, 975·36 cubic feet is left for the Loodiana branch, sufficient for an irrigating channel 147 five thousands in length, through British territory; the possible course of this branch is shown in the map. For the calculation of the proportion of the whole supply thus allotted to British territory, we have the following, premising that 22 five thousands of the Nirwanah branch now estimated for, lie in the British district of Thanesur:—

On the Nirwanah line	$(22 + 40 =)$	$62 \times 5{\cdot}68 = 352{\cdot}16$	c. ft. per sec.
„ Kotluh „		$30 \times 6\ 63 = 198{\cdot}90$	„
„ Loodiana „		975·36	„
	Total,	1526·42	

or half the total available supply. The extra 500 cubic feet which can be

passed down the main channel above Surranah, would be allotted to each branch in the proportions of their above calculated discharges. It does not appear necessary to reserve any portion of the supply for navigation, as the depth of the water in the several branches down to the lowest points where such traffic is likely to extend will be sufficient for the purpose.

Dimensions of Channels, &c.

In determining the dimensions of the irrigating channels, besides the velocity of current, another consideration must be taken into account, viz., the importance of reducing, as far as possible, the fluctuations of the surface level of the water. The reasons for this were so clearly given by Captain Dyas in his Report on the Baree Doab Canal project of 1850, that I need not do more than allude to them here; the proportion of depth to width in fair sections of stream on the Western Jumna Canal, was found to be about 1 to 13. In this estimate it has been taken generally at 1 to 14, (for the Baree Doab Canal channels it is 1 in 15,) except where the stream would thus become too shallow for the passage of boats or rafts. On this account, therefore, the minimum depth of water at full supply has been fixed at $2\frac{1}{2}$ feet. The declivities of bed have been so arranged that the calculated mean velocity of current should in no case much exceed 3 feet per second; the excess of slope in surface of country being disposed of by masonry falls. For the purposes of the estimate the bottom width of channel has been reduced by 2 feet at a time according to the discharge required at certain points.

The form of banks is uniform throughout, side slopes of water channel 1 in 1; tow-paths 15 feet wide, at a uniform level of $1\frac{1}{2}$ to 2 feet above full supply; road banks 20 feet wide, either on the level of the natural surface or raised to a height of not less than 2 feet above the tow-path, with side slopes of 1 in $1\frac{1}{2}$, down to the tow-path. Boundary roads, 20 feet wide, on either side, for the country traffic, are also estimated for. The widths of land to be taken up for the canal channels are as follows:—

Central line,	From Surranah to 1st overfall,	550 to 400 feet.
	1st overfall to Nirwanah branch head,	400
	Below Nirwanah branch head, . .	250
Kotluh branch,	From Surranah to 1st overfall,	550 to 300
	Below 1st overfall, ...	300
Nirwanah branch,	. . . .	300

The Escape Channels are calculated to discharge the maximum supply of the Canal at the points where they take off; they will be merely cuts with side slopes of 1 in 1, the spoil thrown up on either side at a distance of 10 feet from the edge of the excavation; the width of land required for No. 1, on the Central Line, will be 200 feet, for all others 150 feet.

The courses of the several branches are shown on the general map (page 146), the figures at intervals along each denoting the distances in lengths of five thousand feet from their respective heads, the central line being numbered from the Canal Head near Keerutpoor; the numbers correspond with those on the sheets of longitudinal sections of Canal Channels.

Central Line below Surranah.

The course of the line between Surranah and the watershed at Barah, on the Trunk Road, was determined by the necessity of diverting the surface drainage from the north-east into one of the heads of the Puttiala Nullah; an extensive sand ridge occupies the watershed between the villages of Bhayr and Mundōphul, on the western side of which there is a very large hollow, covered with water in the rainy season to the extent of 2½ miles in length by 1 mile in width; the floods from the Khurr Nullah and elsewhere, all passing this way towards the Sirhind Nullah. Now, were the line to be carried on a direct course to Barah, this drainage must either be passed over it by a costly masonry aqueduct, or the country to the eastward be inundated for miles, the sand ridge stopping all egress in the direction of the Puttiala drainage. It might be possible to open a passage for it through the ridge, but the cut would be expensive in the first instance and require constant clearing out afterwards; the lengthening of the line, therefore, so as to skirt the eastern edge of the sand ridge seemed unavoidable, besides the advantage thus obtained of a better direction for the spoil banks on the east side which will intercept and divert the surface drainage. From Barah downwards, the line will keep as close to the watershed as possible, skirting the edges of the sand ridges which almost invariably occupy the highest ground in these districts, and terminating in the Cuggur, near the village of Sadunwas, in the Sirsa district. It does not appear to me advisable, with the limited supply of water available, to extend this branch further; the strip of land between the Cuggur and the tail of the Sirhind Nullah below this is very narrow, and so covered with sand, that the loss

by absorption would be enormous. Sand in these tracts is seldom met with in isolated mounds; it usually takes the form of ridges from one to two or three miles in width, along the tops of the watersheds of the courses of drainage lines, lying in greatest quantity to the east of the latter.

The Nirwanah Branch will take off at the 50th five thousand, sufficiently high to allow of carrying the Channel over the Pattiala Nullah, and crossing the surface drainage on its upper portion in a suitable direction for diverting it into the Choa and Puttiala Nullahs on its left bank.

Two Escapes will be required on this line, the first from a point immediately in advance of the deep excavation above the Trunk Road, terminating in the Sirhind Nullah, 10,000 feet in total length. The second, 45,000 feet in length, from the 97th five thousand, into the Choa Nullah, which ultimately joins the Cuggur: the first was originally projected from the 42nd five thousand, near the village of Bhyrompoor into one of the feeders of the Puttiala Nullah, with the view of intercepting the country drainage there, and disposing of it more effectually, but the levels were found to be impracticable. No. 2 should be some miles higher up, but as it is the only line anywhere near the true position, of which we have the levels, it has been taken for the purposes of an estimate.

The *Channel* from Surranah to the first Overfall, is projected on the same declivity as the bed above, viz., 1 in 6,000, in order to reduce the length of deep excavation as much as possible. At the Trunk Road, an overfall of 6 feet drop will be required, below which the slopes of the bed have been fixed as described in *page* 218; three more overfalls, one of 4 feet, two of 3 feet drop, will be required.

The *dimensions of the channel* from Surranah to Barah, have been fixed at a bottom width of 50 feet, with a depth of water of 7·5 feet, solely with reference to the maximum velocity of current and with a view of reducing the quantity of excavation as much as possible: the calculated depth of the stream above Surranah, with a discharge of 3,000 cubic feet per second, being only 6 2 feet, there will be a back water above the Regulator due to the difference of the depths of water, when the full supply is passing down; this, however, can have no injurious effect on the works.

Surranah Branch Head.—The works at Surranah for the Regulation of the Canal supply, I have reduced in extent as much as possible, but the depth of excavation here necessitates a much greater length of connecting revetment between the two bridges than would otherwise have been given.

The Kotluh branch will take off at an angle of 45° from the main channel, the direction of the central line remaining unaltered. The plan of the works is given; a waterway of 64 feet is given to the central line, 50 feet to the Kotluh branch, (the mean waterways of the channels below being 57·5 and 41·5, respectively,) divided on the Central line into four bays, two of 14 feet each, two at the sides 18 feet each; on the Kotluh branch, two at the sides of 18 feet each, with one central bay of 14 feet; the piers nearest the sides 3 feet thick, the central one 2 feet thick, built up to the same level as the tow-path. Masonry floorings of the full length of the piers are carried right across, protected by curtain walls 6 feet deep, up and down-stream; water-wings, sloping tail-walls, and curtains, are added down-stream to preserve the banks from cutting away. The bridges above will be of timber, with a width of roadway of 20 feet; passages 12 feet wide in the clear, are provided for towing under the bridges on either bank; the two will be connected by a circular revetment up-stream. One main object in this arrangement of the works was to bring the bridges as close together as possible, so as partially to obviate the silting up which invariably takes place in the upper channel below the point of divergence. A drop of half a foot is given in the flooring of the Kotluh branch for greater facility in adjusting the supply, as I think it is advantageous to regulate altogether if possible by one bridge, leaving the passage through the central line quite free. The regulation at both heads will be effected by vertical sleepers, their lower ends resting in a groove in the flooring, confined above between two beams resting on the piers or side retaining walls; it was the most economical expedient I could think of, and though in some respects not so efficient as the ordinary method with drop gates, will I believe answer all the purposes of adjusting the supply; it has the advantage of dividing the entering stream into vertical films, by which the impact on the flooring will be diminished, and it can be worked by a couple of men. For the passage of boats or rafts, the side passages can generally be left free, or the cross beams may be raised without difficulty, as in a draw-bridge, by the aid of ropes and pulleys.

At the 45th five thousand, the first *Escape Head* is projected on the right bank, with an aggregate waterway of 80 feet (the main waterway of the escape channel being 75 feet) divided into bays of 10 feet each by piers 3 feet in thickness, the top of the piers level with the tow-path. The roadway over these will be formed by the simplest kind of wooden bridge,

leaving sufficient space on the Canal side for fixing windlasses across the piers; a masonry flooring will be given the full length of the piers, with apron walls 6 feet deep, up and down-stream; circular waterwings and a cross curtain are added down-stream for the protection of the banks. A drop of half a foot is designed in the flooring to assist the egress of the water; the piers are grooved on the Canal side for the reception of sluice gates which will be worked by the windlasses fixed on the piers. A stop dam bridge immediately below the escape could not be conveniently arranged for; regulation however may be effected at the Overfall, a short distance further on, the fall in the bed between the two works being only 1·09 feet.

At the Trunk Road, 1500 feet in advance of the 46th five thousand, the first *Overfall* with a drop of 6 feet has been projected. It is designed as a vertical fall somewhat altered from those which have proved so successful on the Baree Doab Canal; there the cistern below is divided into chambers for facility of repairs without the necessity of turning off the whole supply. It seems to me, however, of more importance to remove as far as possible all sources of injury to the works. Now, the *extent* of the surface of the cistern immediately below the fall, has apparently as much effect in modifying the violent action of the water as its depth; I have, therefore, designed all the falls in this project, with the drop as close as possible to the edge of a cistern of the full width of the canal down-stream. In this and other cases, solely with a view to a saving of expense, the bridge has been placed immediately below the drop wall, which necessitates the building of the piers in the upper half of the cistern; otherwise the best arrangement for the stability of the work would be to place the drop in the alignment of the down-stream head wall of the bridge; were the bridge removed below the fall and cistern altogether, its cost would be much greater. An aggregate waterway of 75 feet is given through the piers; the drop wall has been placed 2 feet above the line of head wall of the bridge, sufficient I think to allow the water to fall clear; the cistern below is 60 feet in total length with a uniform depth of 5 feet below the bed. Waterwings and a cross curtain are added down-stream for a length of 130 feet from the bridge, giving a circular space of about 130 feet in diameter down-stream, in which the water may boil and eddy before resuming its normal velocity in the earthen channel. This arrangement is less costly than the waterwings with sloping tail-walls, and in cases where the action of the water is that of boiling and eddying rather than

that caused by accelerated velocity, it is at least as efficacious, as far as I have been able to judge. It was not adopted in the Surranah Regulator, only on account of the extra width of excavation required which at such a depth would have somewhat increased the expense. The bridge here, being for the passage of the Trunk Road, has been designed of masonry with a roadway 20 feet wide between the parapets; an inlet for drainage, which will collect on the up-stream right bank, has been arranged for, discharging itself into the canal through the abutment.

Another design for this work will be found, with a *Lock Channel* added on the right bank. No provision is made in the estimate, on the score of expense, for a separate channel and locks round the overfalls, but it appears to me possible, with vertical overfalls, to provide for an uninterrupted navigable passage at a small additional outlay; I have accordingly drawn out this second design similar to the first, in all essentials, except the addition of the lock chamber; the addition to the estimate which such lockage would entail will be shown hereafter. I am aware that such an arrangement was adopted in several of the overfalls on the Eastern Jumna Canal, and Sir P. T. Cautley, in his last report on the Ganges Canal, states that none but those in the southern division were ever used, probably on account of the danger arising from the proximity of the open overfalls. The circumstances are, however, somewhat altered here, and the velocity down-stream is not accelerated as would be the case with an ogee fall. The lock chamber on the Eastern Jumna Canal was an integral part of the overfall, and was always left open when not required for the passage of boats or rafts, which, with careless boatmen, must have been a source of great danger. The present design provides a lock chamber attached to the overfall, but *in addition* to the width necessary for the passage of the canal supply, so that the gates, either upper or lower, could be constantly kept shut. The entrance to it would be 145 feet above the overfall drop, and a floating boom composed of logs of wood fastened together at their extremities is projected to extend obliquely upstream from the end of the lock pier to the middle of the channel, attached there to a screw pile or beam driven into the bed, or (which would perhaps be the best) to a masonry pier built in the centre of the stream, the other end being fixed securely to the wall of the lock chamber; a similar boom would extend from the centre of the stream to the other bank. With such a fender, strongly made and fastened securely at the apex, there would

be in my opinion, little risk of any floating body passing down to the fall.

The three Overfalls below this are similarly designed, but with timber bridges in lieu of masonry.

At the 50th five thousand, we come to the *Nirwanah Branch Head*, the design of which is similar to that at Surranah; the waterways of the channels below are—on the Central line, 49·5 feet; on the Nirwanah branch, 58·1 feet; the corresponding waterways in the regulator are—Central line, 54 feet, divided into three bays of 18 feet each; Nirwanah branch, 60 feet, divided into two bays of 18 feet each and two of 12 feet each; a clear headway of 10 feet above level of full supply is given under the bridges, with tow-paths on either bank.

The *Escape Head* at the 97th five thousand will have an aggregate waterway of 30 feet in three spans of 10 feet each, with a drop of half a foot in the flooring projected similarly to Escape Head, No. 1.

Between Surranah and the 77th five thousand, *ten Bridges* will be required, which, with the branch head and overfalls, will give *fourteen crossings*, or about 1 in 3 miles. Below this, to the termination of the line, *eleven crossings* are provided for, or 1 in about $3\frac{1}{2}$ miles, two of which will be bridges on frequented roads, one across an overfall; eight will be *Fords* (where the depth of water does not exceed 2·5 feet) formed by laying a 9-inch layer of kunkur, 20 feet wide across the bed, protected on either side by thin masonry aprons 1·5 feet deep, ramps down to the bed formed on either bank on gradients of 1 in 10.

Rajbuha Heads.—Main water-course (or rajbuha) heads are estimated for at the rate of two (on either bank) in every $3\frac{1}{2}$ five thousands; they will be simple arched culverts of masonry, under the banks, or revetted masonry passages, bridged with timber with a uniform water way of 6 feet, fitted with sluice gates; the direction of the central line of arch at an angle of about 45° to that of the Canal, to obviate, as far as possible, the silting up in the channel at the head. These masonry outlets are an absolute necessity for the proper regulation of the supply to the rajbuhas; though, I believe, it would be advisable at first to give temporary openings; once the discharging capacity of each rajbuha was well ascertained, the sites for the permanent heads could be determined on, and the sooner they were built the better.

Six 1st class, and twelve 2nd class *Chokies*, will be required from

Surranah to the termination, the former at intervals of 15 miles, two of the latter between each pair of 1st class chokies, or about 5 miles apart. The works of this description along the several lines will serve as residences for the European establishment during the construction of the works; ultimately, they are intended only for halting places.

Kotluh Branch.

The position of the head and first reach of this branch has been described before; it is projected in a straight line to a point near the town of Budlah, where it reaches the watershed in a length of about 8 five thousands from the Surranah head. From this onwards it will keep as close to that watershed as possible, except where it is occupied by sand ridges; in the neighbourhood of Sirhind, and for some miles below, it will require some further close examination of the ground to determine the precise line, the several lines of drainage being very confused, in such cases the level is almost useless. The drainage, the head of which is shown near Chumkour, has no defined channel till it reaches Kotluh; its course is marked only by a succession of jheels, with intervening low ground; immense sand hills line its edges in parts, the ridge to the east of Kotluh being some three miles wide, hardly an acre of it culturable; below this, down to Dabwallee, in Bhuttiana, the hollow is more or less defined, edged by sand hills on either side; which, however, are said by the country people to be of no great depth. At a distance of two or three miles on either side, the soil is hard and very fertile. It is locally called "Nahavohul," and tradition has it that a river once flowed in its bed, where river sand is now met with at depths of from 7 to 9 feet below the surface. On the watershed, there is no great extent of sand to be found down to the neighbourhood of Soonam, a noted resort of Hindoo pilgrims, situated on the banks of the Sirhind Nullah. Sand ridges commence here about the 60th five thousand from the head, and continue more or less to the present termination of the line in the bed of an old drainage, communicating with the Cuggur some miles further down. It will be possible to carry it some forty miles further into the Gooduh pergunnah of the Sirsa district, where, as far as we could hear, the soil is hard and little sand to be met with. Our present estimate is limited by the extent of the levelling.

The first 15 five thousands, (down to the Trunk Road,) being almost

all in deep excavation, *the dimensions of the Channel* have been calculated, as described for the first reach of the central line below Surranah. The declivity of bed being 1 in 6000, and the required discharge 835 cubic feet per second, the consequent width at bottom with a depth of water of 7·5 feet, is 34 feet. Below this it will be observed that as long as the slope of the country surface exceeds that required for the Canal, I have given the maximum declivity to the bed admissible within our limit of a mean velocity of current not much exceeding 3 feet per second, the rate of declivity increasing inversely as the required discharge of the channel; below this the declivity of bed is made to conform as nearly as possible to the natural surface. To overcome the superfluous slope *five Overfalls* are required, two of 8 feet drop, one of 6 feet, and two of 3 feet each; all of similar design to those on the Central Line; the first overfall with a drop of 8 feet, being situated on the line of the Trunk Road, will be bridged by masonry arches, the remainder with timber.

Two Escapes are projected, the first taking off on the left bank close below the Trunk Road overfall, and tailing into the Sirhind Nullah, in a length of 15,000 feet, the bottom width 58 feet; a mean waterway of 60 feet is given to the head divided into six bays of 10 feet each. No. 2 will also take out on the left bank and tail into the Sirhind Nullah in a length of 28,400 feet, at a distance of 28 five thousands further down; the interval between the two escapes will be increased at the time of construction; they are projected in their present positions for the reasons assigned in the case of the 2nd escape on the central line, the lines of levels adjoining them being the nearest to their true courses. No. 2 escape head, is designed with a waterway of 50 feet, divided into five bays of 10 feet each; in all other detail they will be similar to the central line escapes.

Twenty-five Crossings are provided for from the head to the present termination of the line, or 1 in about 3½ miles, five at the several overfalls, and twenty by bridges, the latter all of timber. No *fords* have been given, the minimum depth of water in the canal channel being 2·8 feet.

Seven 1st class and thirteen 2nd class *Chokies*, are estimated for, at the same intervals as elsewhere, as well as *Rajbuha heads* below the deep excavation.

NIRWANAH BRANCH.

Between the head of this branch and the crossing of the Puttialla

Nullah, the line more or less intercepts drainage from the north-west. The longitudinal section shows two distinct ridges, that nearest to the Puttiala Nullah being the watershed between its drainage and that of the Choa Nullah; shallow cuts will be required through these ridges to divert this cross drainage into the western feeder of the Puttiala Nullah. Shortly after passing the Puttiala Nullah, the line reaches the high watershed between it and the Cuggur, along which it will continue up to the point of divergence to the crossing of the latter; sand ridges lie more or less on this course which the line will skirt, with the exception of a narrow one on the edge of the Cuggur valley. Between the Cuggur and Sursoottee the soil is generally hard and clayey, and on account of the very small declivity of the surface, the ground is covered with water to a large extent in the rainy season, while in the dry hot season, on account of the deficiency of sand, it becomes so caked as to be almost useless for cultivation; the heat of this baked dark ground becomes sometimes so great, that even the villagers say they cannot leave the shelter of their houses from about 9 A.M. till 5 P.M. at that season; no wonder then that little or no cultivation is found along this tract. At the edge of the valley of the Sursoottee we come to the high land of the district of Nirwanah, and a soil very different from any we have hitherto met with, only limited in its capabilities for cultivation by the extent to which irrigation can be supplied. In spite of the deficiency of rain-fall and depth of the wells, large and populous villages are scattered over its surface; in many villages there are no wells, drainage water collected in large jheels or tanks supplying the necessities of the inhabitants and their cattle for about nine months in the year; in the hot winds they almost universally dry up, and the villages are deserted until the jheels are again filled by the rains. Our estimate provides for a channel through this district only as far as the town of Nirwanah, the limit of the last season's longitudinal levelling; here the line is on the watershed between the Cuggur and Chittung, and there is no doubt of the possibility of carrying the channel along it for some fifty miles further.

Sections of the defined channels of the three nullahs or rivers as well as of their inundated valleys, at the points where my levels crossed, will be found in the sheets of sections. The Puttiala Nullah, which has the best defined channel of the three, it is proposed to cross by an *Aqueduct*, with an aggregate waterway of 125 feet, divided into five arches of 25 feet span

each, for the passage of the floods of the Nullah, the Canal channel above being 58 feet wide, the mean width of the earthen channel up-stream; the arches are sprung from the level of the highest flood. Now, the area of flood stream in the defined channel is 656 superficial feet, that of the adjoining inundation 2746·5 superficial feet; the velocity of the current in the latter is very small. For the passage of the whole of this, the waterway provided is 1687 5 superficial feet up to the springings of the arches of the aqueduct, besides the spaces included between the chords and crowns of the five arches, which have a uniform rise of 3·35 feet. The details of the work are very similar to those of the Roopur aqueducts; the soil being firm hereabout and the bed of the Canal very little raised above the natural surface, the protective sand-cores in the embankments on either side have not been considered necessary.

The passage of the Cuggur is a more difficult business both on account of its greater volume and extensive inundation. The flood waterway where my levels crossed is 2725·5 superficial feet, the water rising 20·5 feet above the level of the bed, in a channel with a mean width of about 100 feet—the valley on the right bank is covered in floods to the extent of about 3½ miles wide but how much of this is owing to natural inundation, and how much to badly constructed water-courses, which have been long in existence in this neighbourhood, I cannot say; one thing is certain, that the velocity over this flooded surface is very small indeed. For the passage of the deep channel an *Aqueduct* is proposed, similar to that for the Puttiala Nullah; but to carry the bed of the Canal at such a level that the flood mark of the river should not be above the level of the springings of the arches, it will be necessary to cross the Cuggur at same point lower down its course. I have designed the work on that supposition. On the present line the floods would rise to the crowns of the arches. The aggregate waterway given under the work is 150 feet divided into 5 spans of 30 feet each; the piers 16·5 feet up to the springings; the arches, segments of 60°; the versed sine being 4·02. A thickness of 2·5 feet has been given to the arches, covered by half a foot of flooring; the Canal waterway above is 56 feet in clear width; the bed under the arches will be floored with a 2-foot layer of kunkur blocks, carried out to a length of 25 feet, up and down-stream. The inundation waters it is proposed to pass through the Canal by means of an Inlet and Outlet, similar to that described below for the Sursootee; the waterway for both inlet and outlet

to be 100 feet, divided into ten bays of 10 feet wide each. The total superficial area of waterway thus provided would be:—

Under the aqueduct, ...	2,475	s. ft.
Through inlet and outlet, ...	400	„
Total, ...	2,875	„

Captain Cunningham, in his report, gives the flood section of the Cuggur *after* its junction with the Puttiala Nullah as $140 \times 29 = 4060$ superficial feet, at a point where it does *not* overflow its banks; so that assuming the waterway given for the Puttiala Nullah (1687 superficial feet) to be correct, I believe the waterway I have given to the Cuggur works will be ample for any demands that could be made on them.

Passage of the Sursoottee.—Between the 46th and 47th five thousands, the line reaches the edge of the inundated valley of the Sursoottee, which is here covered with water to a greater or less depth in the rains, for a width of nearly $5\frac{1}{2}$ miles, the central channel being only 50 feet wide by 8 feet deep; the low land on the right bank is covered for the greater part with "shora," or earth strongly impregnated with it, into which the foot sinks at every step except where overgrown with grass; this circumstance alone would tend to the supposition that the inundation in this valley was almost "still" water; the whole of the inundated space on the left bank is a sheet of rice fields. The works proposed here are an *Inlet* and *Outlet*, with a *Stop Dam bridge* to prevent flood water passing down the Canal. The aggregate waterway of Inlet as well as Outlet will be 200 feet, divided into twenty bays of 10 feet each, by piers $2\frac{1}{2}$ feet in thickness; a roadway of timber will be formed over both inlet and outlet. Masonry floorings are given to both; revetments on the Canal side are connected by curtains right across the bed; the foundations of all will be sunk to a uniform depth of 6 feet below the bed. The Stop Dam bridge will have a waterway of 52 feet (equal to the mean waterway of Canal channel) divided into three spans, two of 18 feet each, one of 16, wooden superstructure of the usual design, and tow-paths 8 feet wide under the side spans. The regulation will be effected in the inlet and outlet by sluice gates and windlasses, and in the stop dam bridge by horizontal sleepers. The data for the determination of waterway for the Sursoottee are imperfect. By referring again to Captain Cunningham's report, I find that the section at the broken bridge of Polur where apparently the river does *not* inundate its banks, is $70 \times 9 = 630$ superficial feet, but considering that

the depth of flood as well as velocity in the place where my levels crossed, are much less than could be the case in a confined channel, I have given more than double that amount of waterway to the woik, viz., $200 \times 7 = 1400$ superficial feet, an allowance more than sufficient, I believe, for the highest flood. With such an outlet, the ordinary Canal embankment will be strong enough to resist the pressure of the inundation across the valley; these works would be constructed where the present defined channel of the Sursoottee crosses the Canal line.

Two Overfalls with a drop of 9 feet each will be required, to overcome the excessive slope between the Puttiala Nullah and Cuggur crossings; they will be identical in details of design, with those described before; the aggregate waterway for each 65 feet, divided into five bays of 13 feet each, with wooden bridges, having a 12 feet width of roadway.

Twenty-five Crossings are provided for along this line, or one in about three miles; two by the stop dam bridges at the Cuggur and Sursoottee; two by overfall bridges; the remaining twenty-one by timber bridges of the usual design, the width of roadway being either 12 feet or 20 feet, giving a clear passage of 10 or 18 feet wide inside the railings, for single or double traffic; it may be found necessary hereafter to construct a masonry arched bridge on the line of the Puttiala and Umballa road, but at first the temporary structure will answer.

No separate escape channels will be necessary on this line—the outlets at the Cuggur and Sursoottee being sufficient for the purposes of regulation.

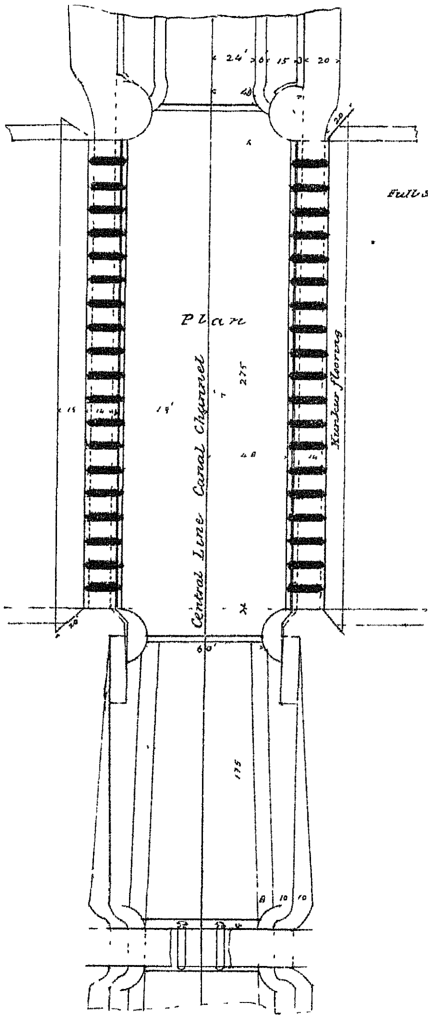
Six 1st class and ten 2nd class *Chokies* will be required. I have given one 1st class in addition to the number required by the limit of one in every fifteen miles, in consideration of the number of heavy works between the Puttiala Nullah and the Cuggur.

RATES OF LABOR, MATERIALS, &c.

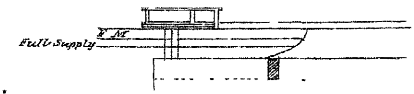
The rates of the different descriptions of work as well as the cost of bricks have been mainly taken from those ultimately obtained on the Baree Doab Canal, the circumstances of the two works being to a great degree similar; the demands of a new work on an extensive scale so alter the existing market prices of everything that it would be useless to base any

SUTLEJ CANAL PROJECT.

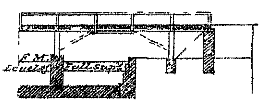
Inlet and Outlet for Sursooltee_Nirwanah Branch



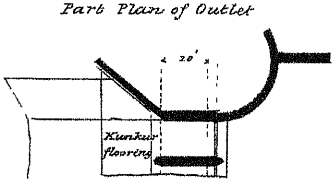
Part Elevation of Outlet



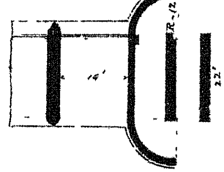
Half Section Dam Bridge



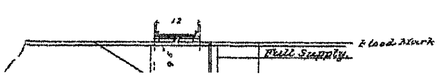
Part Plan of Outlet



Part Plan Dam Bridge



Cross Section Outlet



estimate on them. The cost of the *groined spurs* of open piling is taken from a statement of actual expenditure on the Western Jumna Canal; the rate of kunkur masonry from the Ganges Canal Works. *Limestone* is procurable from the beds of most of the torrents above Roopur, at no great distance from the Canal line; *jungle wood* for burning it is scarce on the low hills close to the line, but is said to be in abundance higher up in the districts of Hindour and Nalaghour, also in the Hoshyarpoor district on the right bank of the Sutlej; which, however, I had no leisure to examine personally. *Kunkur*, fit for burning into lime, is found from Roopur downwards. "*Oopla*," for fuel is as usual scarce and dear near the foot of the hills, in the pastoral districts below it appears to be in abundance. *Brick* buildings abound all over the Sutlej valley, and in the villages along the branch canals, many of which, old and tumble-down forts, and the like, will, I have no doubt, supply a good quantity of ready made material; in some of the lower districts where villages are more thinly scattered and cattle few in number, "koora," (the village refuse,) the usual material for burning bricks, and the best, will be deficient; here, however, the number required will be small. Blocks of hard *kunkur* and *conglomerate* are to be found all over the ravines in the low hills below the Sursa Rao; and as I have mentioned before, when describing the works in the neighbourhood, *boulders* of all sizes are procurable from the beds of the Sutlej, Lohund, Kalee Koondwalee, and Sursa, besides other small hill torrents. On the promontory of the bangur, two miles below Roopur and close to the Canal line, a very extensive bed of first-rate block kunkur exists, visible above the surface in many places, but nowhere, as far as I could ascertain from villagers on the spot, deeper than 2 or 3 feet, varying in thickness from 1 to 4 feet; judging from the specimens of it in numerous buildings and wells in the neighbourhood, it seems fit for any kind of masonry. The roadway over the old bridge at Sirhind is floored with similar material, said to have been brought from Roopur, and appears to have stood the wear and tear of the traffic, for, we might say, centuries, better than any other material used for that purpose in these provinces. The existence of such a quantity of it in its present locality is a fortunate circumstance for these works if they be carried out, for, independently of its value in the construction of the heavy masses of masonry, it affords us the means of covering the more exposed portions of our works, such as crests of falls, &c., with a cheap and efficient substitute for stone. Experience has fully proved that, where

there is little extraneous pressure, if the facing of the masonry work exposed to the violent action of water (especially when loaded with silt) be of some hard material, it matters comparatively little what the body of the work may be composed of, provided it be some substance unaffected by the presence of mere humidity; were such a material everywhere available, the thickness usually given to many parts of our works might be much reduced. Where bricks only are used the facing is necessarily expensive; only those semi-vitrified and laid with the finest possible joints, will at all stand the continued action of water running at a high velocity; plaster is certain to be washed off—and even with the best bricks and finest workmanship deep furrows may often be seen ploughed into the masonry. *Block kunkur* is found in places along the course of the Cuggur, and in the Hissar district. *Deodar timber* is procurable now at the Roopur Ghât at the rate of two cubic feet for the rupee, but as yet only a small quantity comes down the river annually; common *fir* (cheer) is in abundance at the rate of four cubic feet for the rupee; what quantity the forests up the Sutlej can supply of either, I cannot say. Along the banks of the Cuggur, between the hills and its entry into the Thanesur district, extensive groves of *keekur* are found here and there, some of very large dimensions, admirably suited for bridging purposes—the Nirwanah branch lies for miles together through uncultivated tracts covered with jungle shrubs and trees, some of very large size, chiefly in the vicinity of the Cuggur and Sursoottee.

The allowance for *Contingencies*, 10 per cent. on the cost of the works added to the estimates, is intended to cover all expenditure on such items as "compensation for trees, wells, &c., &c.," taken up with the land, "conservancy arrangements," "office contingencies," "temporary shelter for workpeople, &c.," "survey and lining out," and "tools;" it is the proportion of expenditure found necessary for those purposes on the works of the Baree Doab Canal. The per centage for *Establishment* on total cost of works, including contingencies, on those works, was 10·6. I have increased this in the present estimate to 12 per cent. to allow of additional supervising establishment; there were few of the officers employed on the Baree Doab Canal who were not more or less injured by the incessant toil both mental and bodily. It will hardly be considered advisable to repeat the experiment.

Probable Cost of Entire Project.

The possible prolongation of the Kotluh and Nirwanah branches, with a proposed branch through the Loodiana and Ferozepoor districts down to Bhuttiana, have been elsewhere described, and are sketched into the general map; it only remains to show their probable cost, for which we have very fair data from the estimate now submitted. Taking the last 15 five thousands of the Nirwanah and Kotluh branches, as now estimated, the average cost per *five thousand*, comprising excavation of channel, chokies, rajbuha heads, and bridges, (the last bridge on each being taken as the basis of calculation,) with percentage for contingencies and establishment, is Rs. 7,426 for the former, Rs. 10,690 for the latter; this, it is evident, is a very safe estimate; the channels, and consequently the contents of the excavation, and length of bridges decreasing inversely as the distance from the head. The proposed extension to the Nirwanah branch being 61 five thousands, and for the Kotluh branch 40 five thousands; we have the total cost if completed of the

Nirwanah branch, Rs. 7,69,228 + (51 × 7,426) = Rs. 11,47,954
Kotluh branch, „ 14,51,836 + (40 × 10,960) = „ 18,79,436

For the *Loodiana branch* this estimate of cost of the Kotluh line may be safely taken, the circumstances of both being very similar; the declivity of the country surface must evidently be very nearly the same on the two lines, and there will be deep excavation, about 22 five thousands, immediately below the head of the Loodiana branch; the irrigating length of the latter, I have shown elsewhere, may be 147 five thousands; the total length, if the head be near Surranah would therefore be 147 + 22 = 169 five thousands; we have then

$$\underset{141}{\text{Kotluh}} : \underset{169}{\text{Loodiana}} :: \underset{18{,}79{,}436}{\text{Rupees}} : \frac{169}{141} \times 18{,}79{,}436$$

Cost of *Loodiana branch*, = Rs. 22,52,657.

The cost of the project, therefore, if fully carried out would be—

	Rs.
Central line, through the Sutlej Khadir to head of irrigation,	37,52,076·70
Central line through the Sutlej Khadir below head of irrigation,	13,26,499·17
Nirwanah branch, ...	11,47,954·24
Kotluh, „	18,79,436·56
Loodiana „	22,52,657·00
Grand Total, ...	1,05,98,623·67

The total is somewhat in excess, as the Loodiana branch would probably be taken off from the Kotluh line a few miles below the Surranah head, the intervening portion of channel being widened to receive the supply for both branches.

The above estimate does *not* include *Lockage.* If it be considered advisable to render the branches navigable throughout, and the design above described for a single lock chamber attached to each overfall be approved of, the additional expense would be as follows :—

	RS.
Cost of the Barah Overfall, Estimate No. 19, ...	18,475·94
" with Lock, " " 20, ...	34,074 13
Difference due to lock, ...	15,598·19

Now the cost of a lock chamber varies comparatively little with the depth of drop, we may therefore very safely assume Rs. 15,000 as the excess on each overfall, or 2,40,000 Rs. extra on the whole line for *single* lockage. Double lock chambers might be necessary on the Loodiana and Nirwanah branches; not, I think, elsewhere. All the other works on the lines included in the present estimate are designed to allow of the free passage of boats and rafts, so that no alterations to them will be necessary, to allow of uninterrupted navigable communication; this, of course, adds materially to the estimate, but alterations after the admission of water into the canal would involve a very much larger outlay; and in some cases, as in superpassages, &c., an almost total reconstruction of the works.

The lengths of the several lines in miles (of 5,280 feet each) are as follows :—

	Miles.
Central line through Khadir, &c, ...	27·76
" remainder, ...	85 87
Nirwanah branch, ...	121·21
Kotluh "	135 64
Loodiana "	160 03
Grand Total, ...	530·51

Mills are not estimated for in connection with the works; past experience has fully proved that they will always give a remunerative return when constructed in favorable localities.

I have not considered it necessary here to estimate for *Rajbuhas*. Rs. 1,000 per mile may be assumed as the probable cost, and three miles of rajbuha to one mile of irrigating canal channel. The rate of water-tax I have elsewhere assumed in calculating the profits of the project, is taken from a canal where the cost of rajbuhas has hitherto been defrayed by the cultivators themselves; if constructed by the Government, a corresponding increase would of course be made to the water-rate.

Income, Expenditure, and Profits.

From the report of the Superintendent General of Irrigation in the North-Western Provinces, for the year 1860-61, it appears that the returns of the Eastern Jumna Canal for that year, show a rate of Rs. 286 per cubic foot of discharge at the heads. It is not likely that the duty done by the water in one of the driest years on record will be less in years of average rain-fall; I think, therefore, we may with safety assume Rs. 280, as the yearly value of a cubic foot of discharge at the head of irrigation. By the same returns, one cubic foot of discharge is sufficient for the irrigation of 296 acres, and the rate of current expenditure (for maintenance and repairs) was Rs. 120 per cubic foot of discharge per annum. The increase of land revenue from the introduction of canal irrigation we may take at the very low rate of Rs. $1\frac{1}{2}$ per acre per annum; I believe it to be far below the mark, but it is as well to show only the minimum rate of profit. As to the present rate of land-tax, over by far the largest proportion of the country which will come under the influence of these Canals, Rs. 1 per acre, per annum, may, I believe, be taken as the outside average. The quantity of land required for the canal channels now estimated for is 12,928 acres. For the Loodiana branch and the prolongations of the Kotluh and Nirwanah branches, 9,549 acres will probably be required; we have therefore a total of land occupied by the canal works = 22,477 acres. Now if we take the full annual rates for 3,000 cubic feet, and half rates for the extra 500 cubic feet, available for the Khureef crop only; supposing also that the works may be completed in six years, we have—

			RS.
Water-rent, ...	3000×280	=	8,40,000
"	500×140	=	70,000
Increase of land revenue, . . .	$3000 \times 290 \times 1{\cdot}5$	=	13,05,000
" " . . .	$500 \times 145 \times 0{\cdot}75$	=	54,375
	Total *Income*, ...	=	22,69,375
	Deduct.		
Annual current expenditure, ...	3000×120	=	3,60,000
" " "	500×60	=	30,000
Loss of land-tax, annually, on 22,477 acres, about, ...			35,000
	Total, . .		4,25,000
	Nett Income, Rs.,		18,44,375

Total of present Estimate,	1,05,98,623
Add compensation for 22,477 acres taken up at 6 years purchase,	2,10,000
Ditto loss of land-tax for 6 years on 22,477 acres,	2,10,000
Grand Total *Expenditure*, Rs.,	1,10,18,623

From which we obtain a probable return of 16·7 per cent. per annum from water-rent and increase of land-tax *alone;* navigation returns I have not estimated, as the cost of lockage is not included in the estimate; from the returns of the Ganges Canal even up to the present time, Rs. 50,000 per annum would be the minimum of transit dues.

Though temporary expedients have been adopted in so many instances in this project, showing consequently a less outlay in original construction, it may be useful to compare its cost with that of other similar works. Taking the ultimate original cost of the Ganges Canal works at Rs. 2,00,00,000, and its discharge at 6,750 cubic feet per second; that of the Baree Doab Canal at Rs. 1,35,09,491; and its discharge 3,000 cubic feet per second; we have for the

Ganges Canal, Rs. 2,963 per cubic foot of discharge.
Baree Doab Canal, Rs. 4,503 " "

These rates include cost of lockage throughout. For the present project without lockage—*Sutlej Canal*—Rs. 3,261 per cubic foot of discharge. Nothing has been included in our estimate except what appeared absolutely necessary to the efficiency of the works, not even a single ghât. An Abstract Statement showing the cost of different divisions of the project is given further on.

The heavy outlay on the original construction of Irrigation works in these provinces has been ere this attributed in great measure to useless expenditure on ornament, "bridges with expensive ghâts," &c., and been contrasted unfavorably with the cost of works for like purposes in other parts of India. I leave the abstract of this project to speak for itself; the figures will show how small a proportion of the entire cost is devoted to works in which ornament is *possible*. A like result would, I have little doubt, be obtained from the Statements of Expenditure on other similar works. The excavation of the Canal channels, and the works connected with the natural drainage lines of the country, have always comprised by far the largest proportion of the original outlay on any irrigation project, and so far from these having been reduced in size or cost by the growth of experience, they have hitherto been steadily added to, because of the serious evils attending the adoption of temporary or inefficient expedients, which year by year become more manifest. That irrigation, without the exercise of due precautions against intercepting the natural surface drainage, is anything but a blessing to the country, no one practically acquainted with the irrigated districts of India, will I think, deny. The cost of these precautionary measures will vary of course with the physical features of the country. If it be asked why the Madras Irrigation works cost less in proportion to the income derived from them, than those in Northern India, the difference in the declivities of the country traversed by the canal channels, is sufficient to account for a large proportion of the difference in cost. Other valid causes might be adduced were this the proper occasion to enter into the question fully.

One other source of increase of cost in the Canal projects of late years in these provinces, is the necessity of providing for a navigable communication throughout, which involves, besides lockage at the overfalls, increase of excavation in the formation of tow-paths, and considerable additions to every bridge to give towing passages on either side, as well as extra height to afford headway for laden boats. Navigation appears to be satisfactorily combined with irrigation on the Madras canals, and here again the small declivities come in to their aid. In a Report of Col. Sir A. Cotton's, dated the 16th June 1852, on some of the Godavery irrigation channels, he mentions a mile an hour (or 1·47 feet per second) as the maximum velocity which ought to be allowed in the current of a navigable channel; were this to be taken as the basis of our calculations, the cost of our works in

excavation, and overfalls to overcome the superfluous surface slope, would be well nigh doubled. It would probably be a cheaper and more efficient plan to construct an entirely separate channel for navigation alongside the Canal, to which the latter would act as a feeder; the cost of the irrigating channel might then be considerably lessened by the diminution of the excavation for berms (or tow-paths) and the reduction of the width of, and headway under, the bridges to that necessary for the mere passage of the water supply. That navigation is practicable, however, with higher velocities than this, the experience on the Ganges Canal works seems to prove; for with all its faults of excessive velocity of current in the upper divisions, want of towing passages under the bridges, and irregularity of height of tow-paths, the navigation returns are already more than Sir P. T. Cautley estimated them at.

As to the *time* which will probably be required for the construction of the works so far as to commence irrigation, it obviously depends on the speed with which the heavy masonry works in the Khadir, and the deep excavation in the high land can be pushed on; no water can be delivered at the heads of the irrigating branches till these are completed. If funds and *trained* officers are available as required, six years will I believe suffice for the completion of this section; the irrigating lines below could of course be finished simultaneously if deemed advisable.

The possibility of drawing the supply from the Sutlej below the mouths of, at least, some of the formidable torrents which intersect the Khadir, by means of an *Anicut*, the method so successfully practised in Madras, was suggested to me by Colonel Yule; the height of the surface of the Bangur, where the water must be delivered, puts it however out of the question.

Calculations for Discharge, &c.

The formulæ used for calculating the velocities in the various channels are as follows:—

For the canal channels, and others where the mean velocities are not above 4 feet per second.

$$V = 90\sqrt{\frac{R}{S}}$$

For high velocities, such as obtained in hill torrents, &c.

$$V = 93\sqrt{\frac{R}{S}}$$

where—

V = mean velocity in feet per second.
R = hydraulic mean depth in feet.
S = denominator of fraction denoting declivity of bed, the numerator being unity.

They were taken originally from Neville's work on Hydraulics; equations of this form with a co-efficient suited to each particular case, give I believe, quite as good approximations (they are but approximations at best) as the more elaborate formulæ of Dubuat and others. The equation for discharge over "complete" overfalls is—

$$D = \tfrac{2}{3}\, c_d\, l \sqrt{2g} \left\{ \left(d + h_a \right)^{\frac{3}{2}} - h_a^{\frac{3}{2}} \right\}$$

where—

D = discharge cubic feet per second.
l = width of waterway.
$\sqrt{2g}$ = 8·025.
d = depth of water in channel above.
h_a = head due to velocity of approach.
c_d; the co-efficient has been generally taken = ·628, in some cases = ·8.

For discharge over "incomplete" overfalls the equation is:—

$$D = c_d\, l \sqrt{2g} \left\{ d_2 \sqrt{d_1 + h_a} + \tfrac{2}{3} \left(d_1 + h_a \right)^{\frac{3}{2}} - h_a^{\frac{3}{2}} \right\}$$

in which d_2 = difference of level between crest of overfall and surface of stream in *lower* channel.

d_1 = height of drop,—the others having the same signification as in the last equation.

As the declivities are expressed in this report, in terms slightly differing from those ordinarily employed, the following table may perhaps facilitate comparisons.

1	in	6,000	or	·88	feet per mile	(5,280 feet.)
1	,,	4,800	,,	1·10	,, ,,	,,
1	,,	4,700	,,	1·12	,, ,,	,,
1	,,	4,000	,,	1·32	,, ,,	,,

1 in 3,500 „ 1·51 feet per mile (5,280 feet.)
1 „ 3,000 „ 1·76 „ „ „
1 „ 2,500 „ 2·11 „ „ „

List of Rates adopted in the Estimates.

Description.	At	Per
	RS.	
Excavation, canal channel,	2 to 4	1,000 c. ft.
„ in boulders, shingle and water,	12	1,000 „
Embanking,	5 to 6	1,000 „
Puddling,	5	1,000 „
Sand cores,	6	1,000 „
Shingle work in bunds,	10	1,000 „
Boulder and crib-work in spurs and bunds,	12	1000 „
Dry boulder work (filling),	15	1,000 „
Masonry, brick-work in lime cement, .. 16 and	25	100 „
„ boulder in lime cement,	14	100 „
„ mud-work,	3	100 „
„ arching, .. 28 and	35	100 „
„ in wells,	20	100 c. ft.
Stone grooves,	2	per l. ft.
Box-work,	50	100 s. ft.
Crib-work revetment,	10	100 c. ft.
Under-sinking, large wells,	15	„
„ small wells,	8	„
Curb frames, large,	25	each.
„ small,	15	„
Paved slopes,	3	100 s. ft.
Metalling in roadway,	5	100 c. ft.
Flooring, terras,	5	100 s. ft.
„ kunkur, up and down-stream,	6	100 c. ft.
„ brick-on-edge, over arches,	28	100 „
„ dry boulder work,	6	100 „
Roofing, in timber,	·875	per c. ft.
„ on beams and kurries,	30	100 s. ft.
„ flat without beams,	16	100 „
„ „ with beams,	25	100 „
„ thatched,	7	100 „
Timber work,	·625	per c. ft.
Doors, two-third glazed, 6′ × 5′,	25	each.
Falling gates, 11′ × 6′, with iron-work complete,	1·5	per s. ft.
Planks, 11′ × 1·0′ × 0·25′,	12	each.
Gates,	1	per s. ft.
Lock gates,	8	„
Sleepers, 12′ × 0·5′ × 0·5′,	12	each.
Piling at foot of slope,	4	per l. ft.
Piles,	1·5	each.
Groined spurs,	4	per l. ft.
Windlasses,	50	each.
Bitt heads,	10	„
Bar chain, small,	4	per l. ft.
Iron work,	0·5	per seer.

ABSTRACT OF GENERAL ESTIMATE.

Description.	Central line in Khadir.	Central line below Khadir.	Kotluh branch.	Nirwanah branch.	Total.
Excavation of channel, ...	19,00,047·08	8,78,177·61	9,69,908·28	3,89,000 78	41,37,133 75
Drainage works, including head works,* ...	10,86,384·89	...	...	1,27,633·70	12,14,018·59
Overfalls, ...	...	37,620 76	50,113·47	21,888·56	1,09,622·79
Escapes, including heads, ...	...	67,813·48	61,418·05	...	1,29,231·53
Bridges and branch heads, and fords, ...	39,155·79	29,069·70	22,469·00	25,033·00	1,15,727·49
Accomodation for establishment, ...	13,255·04	20,686·32	25,529·96	21,417 53	80,888 85
Roads,...	6,674·00	18,136 00	20,200·00	15,400 00	60,410 00
Irrigation outlets,...	...	25,200 00	28,800 00	24,000 00	78,000·00
Contingencies at 10 per cent., ...	3,04,551·68	1,07,670 39	1,17,843·88	62,437·36	5,92,503·31
Establishment at 12 per cent., ...	4,02,008 22	1,42,124 91	1,55,553·92	82,417·31	7,82,104·36
Totals, Rupees, ...	37,52,076·70	13,26,499·17	14,51,836·56	7,69,228·24	72,99,640·67

* Drainage works include dams, aqueducts, superpassages, inlets, outlets, excavations for drainage cuts, and bunds and spurs connected with hill torrents.

J. CROFTON, CAPT., R.E.

No. LXXIII.

JUMNA FLOODS DIAGRAM.

Communicated by GEORGE SIBLEY ESQ., C.E., *Chief Engineer, E. I. Railway, N. W. P.*

THIS diagram commences from 1st January 1861, and is plotted up to the end of April 1865. The records for 1860 were unfortunately lost.

The horizontal divisions represent feet, and the vertical lines twenty-four hours interval, but the record has been taken twice daily, viz., at 6 A.M. and 6 P.M.

It will be observed that the extreme variations of level between the five years on the 1st January, is less than 2 feet; also that (excluding the present year, which is entirely abnormal) the extreme variation of lowest low water level is 2 feet.

The date of lowest level was for the several years, in their order, as follows:—19th April, 26th April, 21st May, 28th April, 11th February. Thus, for three years out of the five, the date of lowest low water fell between 19th and 28th April, and this may be taken to be the normal average; at that date begins the slight rise due to snow melting. In 1863, this slight rise was more than counteracted by the continued prevalence of strong westerly winds, and the dates of lowest level was protracted till 21st May.

In this year the period of lowest water was reached on 11th February, at which date a slight rise, extending to 1 foot, occurred, and was maintained until 12th March, when the (at that season) extraordinary rise of 3 feet further took place, making the river 3·6 feet higher then the average at that period, and 6 feet higher then the lowest recorded level of that date.

It will be seen that in three years out of four, the great rise due to

the periodical rains commenced on the 19th or 20th June. Last year was one of exceptional drought, and the rise was deferred till 15th July.

In three years out of four, the period of highest flood fell between the 22nd and 26th August, but the highest flood of all, that of 1861, fell so late as 10th September.

The reduced level of highest floods in the several years, consecutively, were as follows :—

In 1861,	... ...	161·60
„ 1862,	... ...	144 50
„ 1863,	... ...	155·00
„ 1864,	... ...	152·50

The highest flood, 1861, is very nearly the same as that of 1832, the highest recorded; and the flood of 1862 is nearly the lowest recorded; so it may be taken, roughly, that the lowest recorded flood rises 30 feet above low water, that an average flood rises 40 feet, and a maximum flood rises 50 feet, above the same level.

The year 1861 was remarkable, not merely from the exceptional height, but also for the long duration of the floods. The river ran for eight days over 155 00, and for four days over 160·00.

The maximum rate measured was rather more than eight miles an hour, or about 12 feet per second (accurately, 950 feet in 81 seconds); for twelve days it ran over 10 feet per second.

At the period of greatest discharge, the mean surface velocity must have been 10 feet per second, and mean velocity of the whole stream upwards of 9 feet per second; the sectional area at that level being about 145,000 feet, it follows that the discharge per second must have reached the enormous amount of nearly $1\frac{1}{3}$ million cubic feet.

G. Sibley.

No. LXXIV.

PUNJAB RAILWAY INSTITUTE.

Designed and Built by EDWIN E. BAINES, ESQ., *District Engineer.*

THE Chief Engineer (J. Harrison, Esq.) and the late lamented Agent, R. W. Stevens, Esq., of the Punjab Railway, in April 1863, taking into consideration the rapid increase of European employés on the Company's works at Nowlukha, Lahore, deemed it advisable that some rational place of amusement and instruction should be formed; accordingly, instructions were given to Mr. E. C. Baines, the Engineer of the district, to prepare a design and estimate, and these having received sanction, the works were commenced in the autumn of 1863, and were available for the members' accommodation at the commencement of the ensuing hot season.

The arrangements consist of a Reading-room, 30 × 21 feet, with small Book-room, and Khansamah's room attached, surrounded with a verandah 8 feet in width; in the rear is a commodious Swimming Bath, 44 × 27 feet, provided with two small dressing-rooms.

The bath gives a depth of 10 feet of water, one half of which will be supplied from the adjacent rajbuha naturally, and the remainder from a well. The bath can easily be flushed out, being connected by a sluice with the Company's culvert.

The Institution is supported by about eighty members. The table is well supplied with books and periodicals. The estimated cost was Rs. 12,571-3-3. The executed cost, Rs. 11,352-6-3.

E. B.

No. LXXV.

LAYING OUT CURVES.

By R. McKennie, Esq., *Assistant Engineer, Mysore.*

Fig. 1.—PX is any right line; it is required to diverge from it at the point A, into a Curve of any Radius, such that the line PX shall be a tangent to the curve at that point.

(1°). Proceeding to the point A, and adjusting the theodolite over it, lay out any angle XAQ that is contained in the Tables, such that there may be no obstruction in the line AQ; and set up a pole in that direction. For example, let us suppose the angle XAQ = 20°, and the radius of the curve six chains.

(2°). Multiply the *Tabular* Semi-Abscissa* and Ordinates (which are entered in the Tables as decimals of one chain, or any other unit, *vide* Formulæ), opposite the angle selected (20° in this instance), by given Radius, for *new* Semi-Abscissa and Ordinates corresponding to the given radius. In the above example:—

						CH.	LKS.
Tabular semi-abscissa,	$\times r =$	·342020 $\times$ 6	=	2·052	=	2	5
1st tabular ordinate,	$\times r =$	·011752 $\times$ 6	=	0·070	=	0	7
2nd ,,	$\times r =$	·022146 $\times$ 6	=	0·132	=	0	13
3rd ,,	$\times r =$	·031224 $\times$ 6	=	0·187	=	0	18¾
9th ,,	$\times r =$	·059722 $\times$ 6	=	0·358	=	0	35¾
10th ,,	$\times r =$	·060307 $\times$ 6	=	0·361	=	0	36

Fig. 2.—(3°). Then from A chain towards Q, to length of new semi-

* Semi-chord ?—[Ed.]

abscissa, or 2 chains 5 links, and let B be the point arrived at, where place a staff.

(4°). Divide the semi-abscissa corresponding to given radius into ten parts, which is at once done by shifting the decimal point one place to the left, and the result for radius of six chains, is $20\frac{1}{2}$ links. We thus get the interval between each ordinate, or space intercepted between each offset from the line AQ.

(5°). Now commence at A, and $20\frac{1}{2}$ links from it on the line AB stick down a peg corresponding to the point a, Fig. 1. $20\frac{1}{2}$ links from that again, on the same line, place another, corresponding to b, and so on, till finally you arrive at B, where a staff has already been placed, and which ought to be $20\frac{1}{2}$ links from the point i, or 9th peg from A.

(6°). Then, from the points a, b, c, &c., h, i, and B, lay off at right angles to AB, the calculated 1st, 2nd, 3rd, &c., 8th, 9th, and 10th ordinates, respectively, that at a being 7 links, at b 13 links, and so on, these extremities being connected will give the required curve.

(7°). To complete the curve, produce the line AB till $BC = AB = 2$ chains 5 links. On this line place a peg, $20\frac{1}{2}$ links from B, corresponding to point i', Fig. 1, and so on, placing pegs in succession till C is reached, which ought to be $20\frac{1}{2}$ links from the last peg, a', placed.

(8°). Then, from the points i', h', &c., lay off the 9th, 8th, &c., ordinates just used, *i. e.*, $35\frac{3}{4}$ links at i', $34\frac{1}{2}$ links at h', &c., and 7 links at a'.

(9°). Should it be desirable to continue the curve, remove the theodolite to C, and make an angle $ACY = 180° - 2XAQ$, which will be in this case, $180° - 40° = 140°$. Set up a pole in the line CY, and proceed precisely as before, the calculations being the same, as will be at once seen from the construction; so that instead of finding the tangent at the point C, and laying off the abscissa from it, we lay off the abscissa from the last one, thus saving time. Thus the curve will be continued from C to D, CD being $= AC$.

(10°). By continually proceeding in this way we may complete the circle, and the several abscissæ will be the sides of a regular polygon inscribed in a circle.

Sometimes, however, rule 9°, is not applicable, from trees or other obstructions in the line of the abscissa, in which case—

Fig. 2.—(11°). Set the theodolite at C, and make an angle ACX′

$= 180 - XAQ = 180° - 20° = 160°$, and set up a pole in the line CX' which will be a tangent to the curve at the point C, and use any other tabular angle $X'CY'$ applying the previous rules; thus the curve will be traced from C to E, or end of abscissa corresponding to tabular angle $X'CY'$. Rule 9° can now be applied for the continuation of the curve by making an angle at E, $CET = 180° - 2X'CY'$, and so on, provided no obstacle prevents the measurement of the abscissa; thus avoiding new calculations so long as the same angle, $180° - 2X'CY'$ is used.

Should it not be desirable to continue using the same angle, we can set the instrument at E, and apply rule 11°, thus finding the tangent ME at that point, and using some other tabular angle, continue the curve in spite of all obstructions.

If the reverting point happened to be at C (the end of the abscissa), we could revert into a tangent by making $ACX' = 180° - XAQ$, as in rule 11°; and so on for the tangent at the end of any abscissa. The general case, however, is, to suppose the reverting point to be situated anywhere in the curve.

Fig. 3.—(12°). Set the Theodolite at C, or end of abscissa, and find the angle δCA; then convey the instrument to δ and make an angle $C\delta Z = XAC - \delta CA$, then the line δZ will be a tangent to the curve at that point; and so on in similar cases.

Fig. 4.—(13°). To construct the S curve, the point of contact of curves being the point δ, find a tangent to the curve at that point; and using any tabular angle, proceed as before, the ordinates and abscissa being on the opposite side to the first curve; by the same means any number of reversed curves can be laid out.

When the radius of the curve is large, a small tabular angle should be used, and *vice versâ*, so that in no case need the abscissa and ordinates be of inconvenient dimensions. The tabular angles from 1° to 20°, at intervals of 15′, are found to answer all practical purposes.

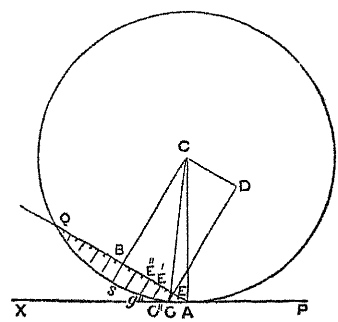
These Tables have been computed from the formulæ appended, with great exactness, and having been tested by the Differential method, have been found to be very accurate, so that they may be relied on. The tabular values have been carried to six places of decimals: any number of places, however, may be used in practice, according to the degree of accuracy demanded.

Though these Tables, with the method of using them, may appear

troublesome, their extreme accuracy on the ground compensates in a great measure for any extra work they may give; and I question if they may not be on the whole quite as expeditiously used as any other instrumental method.

I am aware that there is one method by the chain alone which is very expeditious, and which I invariably use myself extensively when great accuracy is not wanted; this, as well as many useful problems will be found treated in full in "Henck's Field-Book for Railway Engineers," a work which at once recommends itself on perusal.

In conclusion, I in no way claim to be the investigator or calculator of these Tables, but beg to give the whole credit to Mr. William Gartland, C.E., Dublin, to whom I am indebted for many miscellaneous and valuable mathematical investigations in manuscript; and trust they may be found as valuable to others as to myself. I am not aware either that they have ever been printed, or are in any way generally known; indeed I have reason to think they are not, but should they be, my apology must be that they may be useful to men who are not likely to have met with them.



Investigation of formulæ.—Let PX be a tangent to a circle at the point A; draw any line AQ, making an angle with XP at A $= \theta$.

Draw CS perpendicular to AQ, it will also bisect it; and it is evident that SCA $=$ QAX $= \theta$.

Let AE $= \frac{1}{10}$ AB, and draw GD at right angles to AB at E.

$$\text{Now, AB} = r \sin\theta, \text{ but AE} = \frac{1}{10}\text{ AB} \therefore = \frac{r\sin\theta}{10}.$$

$$\text{also BE} = \text{CD} = 9\text{ AE} = \frac{9 r \sin\theta}{10} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (\alpha).$$

$$\text{BC} = \text{ED} = r\cos\theta \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (\beta).$$

$$\text{GD} = \sqrt{r^2 - \text{CD}^2} = \sqrt{r^2 - \left(\frac{9 r \sin\theta}{10}\right)^2} \quad \ldots\ldots\ldots\ldots \quad (\alpha).$$

$$GE = GD - ED = \sqrt{r^2 - \left(\frac{9\,r\sin\theta}{10}\right)^2} - r\cos\theta \quad \ldots \quad (\beta).$$

$$= \sqrt{r^2\left\{1 - \left(\frac{9\sin\theta}{10}\right)^2\right\}} - r\cos\theta.$$

$$= r\left\{\sqrt{1 - \left(\frac{9\sin\theta}{10}\right)^2} - \cos\theta\right\}$$

Let $\frac{9\sin\theta}{10} = \sin x$ from which x can be got

$$\therefore\ GE = r\left\{\sqrt{1 - \sin^2 x} - \cos\theta\right\} = r\left\{\cos x - \cos\theta\right\}$$

Similarly, values for E′G′, E″G″, &c., can be found, each being at a distance from one another $= AE = \frac{1}{10}AB$.

Also $BS = r - BC = r - r\cos\theta = r(1 - \cos\theta)$.

Now, calling AB, the semi-abscissa, and EG, E′G′, E″G″, &c., the 1st, 2nd, 3rd, &c., ordinates, we enter their values, under their respective heads in the tables.

The rules for diverting the line from curve to tangent, &c, are so simple of geometrical proof as to require no demonstration.

R. McKennie.

No. LXXVI.

ROADS AND RAILWAYS IN INDIA.

Re-printed, by permission, from a pamphlet by Sir William Denison, K.C.B., *Colonel, Royal Engineers.*

Looking to the fact that the Government of India, although it has expended large sums upon roads and railways, as well as upon canals, when opportunities of constructing these were afforded, has yet many thousand miles of road to make, and fresh lines of communication to open, I cannot but think that an enquiry into the circumstances which influence the cost of transport in India, and a comparison of the advantages presented by different modes of communication, would be useful, not merely to the Government, but to the capitalists who may be disposed to invest money in works of this kind, and who, of course, would wish to derive from such investment the largest returns.

Such an enquiry, will, I think, tend to prove that the local features of the country, the character of its climate, the pecularities of the people, and the nature of their industrial system, influence, far more largely than many are apt to think, the discussion of questions which would seem, to most, to be simple matters of engineering experience.

Before, however, I enter upon this enquiry and comparison, I must premise that the facts which I propose to classify and arrange, as the basis of any inferences I may draw, have reference to the Presidency of Madras, which occupies by far the largest portion of the southern extremity of the Peninsula of India. There is, however, a marked similarity between the state of things in the different Presidencies; and, with some trifling allowances for local peculiarities, I think that what I have to say about railroads in Madras, will be found applicable to the whole of India.

General aspect of the Country.—The Peninsula of India extends from

Cape Comorin in latitude 8° N. to latitude 20° or 21° W., at which point its width is about 14° of longitude or 800 miles or thereabouts.

A range of mountains from 6 to 8000 feet high runs parallel to the Western Coast at a distance of about 50 or 60 miles from the sea. This range is broken through at one point where there is a gap of about 40 miles in width, the height of which is not more than 1,200 feet above the sea. The fall of the ground to the westward is therefore rapid, while speaking generally, there is a gradual and much more gentle slope to the eastward, which is interrupted, occasionally, by abrupt secondary ridges rising to a height of 2 or 3000 feet. Nearer the East Coast the land slopes gradually towards the sea, at the rate of about 4 feet per mile, in great plains, where there is but little to catch the eye, or to relieve the monotony of the landscape. It follows, from what has been said above, that the rivers flowing to the West Coast have short and rapid courses; though, as they flow through a narrow belt of alluvial soil near the sea, they are often navigable for small craft for some miles from the mouth. Those that flow to the eastward have a much longer course, and, as they drain a much larger area of country, they bring down, during the rainy season, a very heavy body of water; as, however, the supply is but temporary, as will be seen when I speak of the climate, these rivers do not afford any facilities for water communication in their unimproved state.

Climate.—The position of the Peninsula, within the northern tropic, exposes it to the action of the periodical rains. These are modified in their action by the relation of the Peninsula to the great mass of the continent from which it projects, and assume the form of two distinct monsoons. The south-western, which is by far the most extensive in its action, commences about the middle of May, and, so far as the Peninsula of India is concerned, expends its force principally upon the West Coast, and the range of mountains paralled to it, where during the months of June, July, August, and part of September, there is a steady down-pour with an occasional break; the average rainfall may be put at 180 inches.

Of course a large proportion of this water returns rapidly to the sea on the West Coast; the effect being to lessen the saltness of the sea to such an extent as to kill the fish and all the plants which are naturalized in salt water, for several miles from the coast, and to cause thereby a most disagreeable putrescent effluvium along the coast, and for three or four miles out to sea.

A portion of the rain of the south-west monsoon is discharged upon the eastern slopes of the mountain range, and drains into the water-courses which form the heads of the large rivers, such as the Godavery, Kistnah, and Cauvery, which discharge themselves into the Bay of Bengal; causing heavy floods in the lower portions of these rivers. In October the wind veers to the northward of east, and is called the north-east monsoon. It brings with it the rain which it has sucked up in the Bay of Bengal, and discharges it upon the eastern slopes of the Peninsula. The amount, however, of this discharge, which continues at irregular intervals through November and December, is not nearly so great as that of the south-west monsoon. The average of twenty years gives thirty-one* inches as the amount of rain at Madras during the north-east monsoon, and further inland the average is much less, not exceeding thirteen inches.

Rain may be said to fall from May to December in some part or other of the Peninsula; but the $4\frac{1}{2}$ or 5 months from January towards the end of May, may be termed emphatically the dry season. No vegetation takes place, except in situations where water can be found to irrigate the soil; the sky is cloudless, there is nothing to impede the action of the sun upon the ground, which is baked to the hardness of a brick where the aluminous element prevails, and is reduced to a dust where its consistency is less compact.

Cultivation.—From the foregoing description of the climate, it may be inferred that the productiveness of the country depends altogether upon the periodical rains. Should nature pause in her action for a single season, the result of this short cessation would be such a wide-spread famine as would destroy millions upon millions of people, and reduce the country to a desert.

On the West Coast the rain falls with such regularity, and the atmosphere generally is so moist, that few or no attempts are made to retain the water discharged upon the range of mountains bordering the coast. On the east side of these mountains, however, the case is very different. Here the rain is scanty and irregular, and care is taken to secure as much as possible of the drainage of the country. In every water-course, or line of drainage, dams will be seen following each other in regular succession, till all, or nearly all of the drainage water is caught, and retained for agricultural purposes; the surplus, which finds its way into the rivers, is again stopped by *anicuts* or dams constructed across them, from distance to

* Being rather less than the *total* annual rainfall of the Punjab, where the cold weather rains of January and February average from 2 to 5 inches only.—[ED.]

distance, and channels are taken from above these dams by which the water of the river is distributed as extensively as possible. When all this has been done, there is but a small proportion of the cultivated land which is susceptible of irrigation; the remainder is dependent upon the ordinary action of the rains, and is sown with what are termed "dry crops;" namely, various kinds of millet and raghi, and also with oil seeds, gram, and other leguminous plants. This dry cultivation imposes upon the farmer the obligation of completing his agricultural operations rapidly; he cannot plough before the first rains have softened the ground; he cannot sow till he is pretty certain of continual showers of rain. The result is that he is compelled to maintain, or at all events to employ, a pair of bullocks for every five, or at least, for every eight acres of land which he cultivates, as he would not be able, with less animal power, to carry through the various ploughings and hoeings which the land demands. The crop springs up rapidly under the influence of rain, and of a sun nearly vertical, and is ready for reaping in four or five months. It is then reaped, trodden out by bullocks, as was done in the time of Moses, and winnowed by the wind in a manner as old-fashioned as the threshing. When all this has been done, the farmer, unless he has land which he can irrigate, and from which he can get a second crop, has no work for his bullocks during the five or six months of the dry season; they are, consequently, employed in conveying produce to market, and the farmer or cultivator, leaving his land to to take care of itself (which it does by producing a plentiful crop of coarse grass and weeds) attaches his bullocks to a light cart or bandy, and becomes a common carrier, being satisfied, of course, with very small profits, as every penny which he receives, in addition to the amount required to maintain his bullocks, is clear gain.

Population.—The population of the Madras Presidency may be put at 24,500,000, of which about 16,800,000 are employed in agriculture. About 450,000 are congregated in Madras and its suburbs. There are, however, few large towns, though in each district there are three or four towns, about which the population congregates more densely than in the rural districts. As a general rule, the population is more generally diffused over the face of the country than is the case in England, where the agricultual portion of the community forms a much smaller portion of the whole than is the case in India.

Wages.—A necessary result of this dissemination of the people, and of

their employment in the rude processes of agriculture, is that wages are low every where. The capital expended by the different Companies upon Railways and Irrigation Works, has, by increasing the demand for labor, raised *locally*, the rate of wages; but, even now, in parts of the country a little distant from the lines of Railway, from Rs. $2\frac{1}{2}$ to Rs. 4 per month or from $2\frac{1}{4}d.$ to $3d.$ per day, may be considered as the ordinary and average rate of wages; while, generally speaking, the whole of the agricultural labor is paid for in kind. The hire of a pair of bullocks and a man to drive them, and to plough at the same time, is 5 annas or $7\frac{1}{2}d.$ per day.

Roads.—Though men and cattle may be hired at a very low rate, as shown above, yet the cost of transporting commodities must depend very much upon the character of the road over which the traffic is to pass. The main lines of road throughout the Presidency are, generally speaking, in a fair state of repair, much money having been spent upon them. The principal obstacles to ready communications are the nullahs and water-courses, many of which are not bridged; during the rainy season these are torrents altogether impassable; while in the dry season, the river beds are filled with a loose drifting sand across which the ordinary carts or bandies, carrying about half a ton, require to be assisted by many men. The cross roads are in pretty good order for the character of the traffic which passes along them; indeed, during the dry season, roads though deep in dust, do not oppose any great obstacle to the movement of goods or produce. A great proportion of the work of transport is accordingly done in that season; the cost of conveyance being about $2\frac{1}{2}$ annas, or $3\frac{3}{4}d.$ per ton per mile.

During the rainy season the cost of conveyance is much enhanced: in the first place, the roads are soft and damaged by the rain; the bridges are carried away by floods, culverts blown up, &c. The actual labor and risk of conveyance is therefore much greater. In the second place, the rainy season being the working period of the agriculturists, the whole of the animal power of the ryot is expended upon his cultivation, and he cannot spare any to be employed upon road traffic, and there is, therefore, less competition. To set against this, however, there is less traffic at that time of the year, and I am disposed to consider the figures above given as the cost of conveyance, and which were taken from a return furnished by the Commissary General, of the contract price for Government transport, to be a fair average for the whole year.

Railroads.—Of these, the Madras, or South Western line, is completed

from coast to coast, a distance of 406 miles. The North Western, which is eventually to communicate with Bombay, is open for a distance of 41 miles from its junction with the Madras line. The Great Southern of India line, is finished from Negapatam to Trichinopoly, a distance of about 80 miles, but it has yet to be connected with the Madras line by an extension of about 80 miles, which will meet the South West line at a point about 250 miles from Madras. A branch from the Madras line, about 80 miles in length leads to the Militaiy station of Bangalore: this is just completed. When the whole of these lines are finished, there will be a complete chain of Railway communication connecting the principal Military stations in this Presidency with the great depôt at Madras; and this latter will communicate directly with Bombay.

Canals.—Of these there are but few. The Irrigation channels in the deltas of the Kistnah and Godavery are used with great advantage for local traffic; and there is a coast canal, connecting the backwaters of some of the rivers to the north and south of Madras; while the Irrigation Company has on hand a project for completing a line of water communication between Kurnool on the Toombuddra, and the sea on the East Coast.

As a general rule, however, the country is altogether unfitted for this kind of communication, owing to the difficulty of securing, either at or below the summit levels, a sufficient supply of water to furnish the lockage and to meet the very large demand on account of evaporation.

I have given this short sketch of the Madras Presidency, and of the existing means of communication, in order to facilitate the comparison which it will be necessary to make between the result of the Railway system here and elsewhere.

In England and Australia, the *indirect* benefits arising out of the Railway system, afford a full compensation to the country at large for the capital sunk in the Railway. The holders of the Railway shares are losers, of course, to the extent of the difference between the dividend paid, and the ordinary interest upon the capital invested; but every man who travels by rail, and every man who has goods to send to market saves a very large percentage of the amount he would have had to pay, had his means of communication been limited to turnpike roads.

In India, however, so far as the conveyance of goods is concerned, the *indirect* benefit is by no means so great as that which is enjoyed by Eng-

lish or Australian merchants. Here the cost of moving goods is about $2\frac{3}{4}d.$ per ton per mile on the road, while on the rail it may be put at $1\frac{1}{2}d$; that is the cost per rail is to that per road as 2 to 5, while in New South Wales it is as 1 to 4, and in England 1 to 5.

The benefit to travellers in India is very great; the facilities afforded by the Railway have made thousands travel, who in former times never dreamed of moving from their homes. Still, however, the poverty of the people, the very low wages which they receive, taken in connection with the fact that a very large proportion of such wages is paid in kind, would seem to point to the conclusion that years must elapse before any very great extension of passenger traffic will take place, except in the vicinity of large towns. At the present low fare of $\frac{3}{8}$ths of a penny per mile for 3rd-class passengers, the Madras cooly would only be able to travel $9\frac{1}{3}$ miles for his daily wages; while an English laborer would earn enough in one day to carry him 30 miles. A reduction in the Madras rates would, I have no doubt, increase the number of passengers; but it is very questionable whether it would increase the net receipts. If, indeed, the cost of working the Railway in India bore the same ratio to the cost of working in England, as the rate of wages in India does to that in England, the lowness of the Madras rate would not have much influence on its net receipts. But in India the cost of freight has to be added to that of the coal or coke used; the wages of skilled labor, as Engine Drivers, &c., are higher than in England, and though the ordinary labor employed about the stations, and on the maintenance of way, is cheaper than in England, it is not cheaper in proportion to the difference of wages, for one Englishman will probably do the work of *at least* three Natives. On the whole, it will, I think, hardly admit of a doubt that the amount of traffic required to pay the interest of the capital expended upon the construction of the Railway, as well as to defray the costs and charges of maintenance of way, and of locomotive power, must be far greater in India than in England and elsewhere.

Now the interest of capital is one of the heaviest charges against the proceeds of Railway traffic, and when the traffic is comparatively light, and not likely to increase to any great extent, it may be more to the advantage of the Government, and of the country generally, that a description of road should be constructed which involving a smaller outlay of capital, but requiring a somewhat more costly description of locomotive power, would, at a charge little, if at all, in excess of that of the Railway, furnish a return

sufficient to keep the road in thorough repair, pay the interest of the capital expended upon its construction, and provide an amount of tractive power fully adequate to the wants of the people, though the time expended would, of course, be very much in excess of that required by the locomotive line.

I propose, then, in the remainder of this article to investigate carefully the relation between the outlay and the returns upon various kinds of roads in the Presidency of Madras; namely, the Railway worked by the Locomotive engines; the Railway worked by Animal Power; and the Macadamized Road. The first step towards this comparison must be the determination of the amount of passenger and goods traffic which is to be taken as a standard quantity, and in order to simplify the calculations, and, indeed, to substitute matter of fact for matter of inference, I propose to take the amount of traffic upon some given line, or portion of a line of existing Railway, as this standard.

The Madras or South West line of Railway, extending from Madras to Beypore, a distance of 406 miles, partakes too much of the character of a great Trunk line to justify the adoption of the whole or of any portion of it, as a standard of comparison, whether as to outlay or as to the amount of traffic; but the North West line, or the portion of it already completed, viz., 41 miles, may be fairly looked upon, at present, in the light of a branch; and an enquiry into the cost of moving the passengers and goods, stated to have passed over this line, by some more simple system of conveyance, will afford satisfactory data as to the relative advantages of Railways or other roads.

I may observe that the Madras Railway, though it only paid, during the first half of 1863, interest to the amount of ·66 per cent. or 13*s.* 7*d.* per hundred pounds of capital expended upon *the whole line*, did, I have no doubt, pay the full interest of five per cent. upon the cost of the 40 or 50 miles nearest to Madras; but it would be difficult, if not impossible, to attempt to deal with the line in sections, and to attribute to each its fair share of expenditure and receipts. It is only necessary to say that, with an amount of traffic equal to 595,000 passengers, and 960,000 tons of goods in the half-year, the amount of interest was only, as stated above, ·66 per cent. for the half-year, so that 1,200,000 passengers and about 200,000 tons of goods would only pay the cost of traction, of maintenance of way, and $1\frac{1}{3}$ per cent. upon the outlay of capital.

The following is an abstract of the nature and amount of the traffic on the North West line, for the half-year ending 20th June 1863; and the numbers given will, when doubled, form the standard amount of traffic upon which the calculation of the cost of conveyance on the different kinds of roads will be based; the actual cost of the working of the Railway being taken.

Passengers.

1st-Class,	194 × 2 =	388
2nd ,,	1,411 =	2,822
3rd ,,	75,999 =	151,998

Goods.

Tons,	15,711 × 2 =	31,422

The 1st and 2nd-class passengers will be merged into one of say 3,220. The second-class of passengers will consist of 152,000, and the goods will be taken as 32,000 tons. I will now proceed to enter upon a detailed examination of the cost of *Construction*, of *Maintenance of way*, and of *Locomotive power* upon the Macadamized road, upon the Railway for Animal power, and upon the Railway for Locomotive power, with reference to the above amount of traffic.

Construction.

1*st*. *Macadamized Road.*—The data as to the cost of constructing such a road as this have been furnished by the Public Works Department, and the amount given below may be considered a fair average of the cost of such roads throughout the principal parts of the Presidency.

	£	s.	d.
Width of road,	30 feet.		
Width of metalling,	24 ,,		
Cost of earthwork,	166	14	0
Do. of metalling,	163	16	0
Bridges and Culverts,	302	14	0
Sundries,	40	0	0
	£673	4	0

If an addition be made to this sum for the cost of superintendence, &c., bringing it up to £750 per mile run, this will be an ample allowance for any contingency.

2*nd*. *Railway for Horse-power.*—The cost of the earthwork, and of the bridges and culverts, would be rather less on the railroad than on the macadamized road; for, while it is not intended to modify the gradients in

any way, or to add to the cuttings and embankments, except on very special occasions, the width of the road may be less. I do not, however, propose to make any deductions on this account, but shall assume the cost of the earthwork and bridges and ballasting, at the same sum as given for the macadamized road, viz., £750 per mile; setting the metalling against the ballast of the Railway. The cost therefore, of a railroad will be found by adding to the cost of the macadamized road, that of the purchase of rails, chairs, and sleepers, and that of the labor of fixing them.

The weight of the rail used at first on the Manchester and Liverpool line, was 35 lbs. to the yard, and it seems to me that, for horse traction, a rail 28 lbs. to the yard would be amply strong enough; and as 2,000 yards, or an addition of 240 yards to the mile, will be sufficient to cover all sidings, &c., $2 \times 28 \times 2{,}000 = 112{,}000$ lbs., or 50 tons per mile, will be the weight of the rails. These can be delivered at Madras at £8 10*s.* per ton, and an additional 30*s.* per ton, making a total of £10 per ton, will cover the charge for conveyance, so that £500 will be the cost per mile of the rails delivered upon the road. Timber sleepers have been found to decay rapidly in this climate; I should therefore be inclined to recommend the employment of stone blocks as supports for the rail: in many parts of this Presidency, where the gneiss crops out on the surface, the stone block would be far cheaper in first cost, and far more durable than any other description of sleeper; but, as these may not be attainable generally, I propose to allow for the use of the iron pot sleepers, which have been employed on the Railway. For the horse traction line these may be made lighter than for the locomotive line, but I propose to allow for the same weight and price, that is £1 per pair of sleepers with the connecting tie-rod. I shall allow, however, for a bearing of five, instead of four feet: the cost, under these conditions, of chairs and sleepers will be £1,200 per mile.

The cost of laying the railway may be put as on the Locomotive line, at 4½*d.* per yard run, the cost for 2,000 yards would therefore be £37 10*s.*

In order to make the action of this railroad perfect, it should be provided with a line of Telegraph; and the cost of this, judging from the amount expended upon that on the Madras line of railroad will be £90 per mile.

The whole cost of this railroad for animal power per mile will then be as follows:—

	£	s.	d.
Earthwork, including Ballast or Metal, . . .	330	10	0
Bridges, Culverts, &c., ...	302	10	0
Rails, ...	500	0	0
Chairs and Sleepers, ...	1,200	0	0
Fixing Rails, ...	37	10	0
Telegraph, ...	90	0	0
Stables and Rest Houses, ...	50	0	0
Sundries, ...	40	0	0
Superintendence, &c., ...	76	0	0
	£2,627	0	0*

Locomotive Railway.—The cost of this may fairly be put at the same rate £12,000 per mile: this has been the cost of the South West line, and it will in this case, include the cost of the rolling stock required to work the amount of traffic taken as the standard The comparison, therefore between the capital expended per mile upon the different kinds of roads, and the annual charge on account of interest at 5 per cent. will be as follows :—

	Cost per mile.			Interest.		
	£	s.	d.	£	s.	d
Macadamized road, ...	750	0	0	37	10	0
Railroad for Animal power, ...	2,627	0	0	131	7	0
Railroad for Steam power, ...	12,000	0	0	600	0	0

MAINTENANCE.

The next matter for consideration will be the cost of the maintenance of way, that is, the annual outlay required to maintain the road in a state of thorough repair.

This must, of course, so far as the *Macadamized Road* is concerned, depend upon the amount of traffic, while the quality of the materials employed will have some action upon the annual charge. A fair approximation, however, may be arrived at by a reference to the amount commonly allowed for maintenance upon the great trunk lines of road in this Presidency, and Rs. 300, or £30 per mile, would be considered sufficient for a road upon

* This estimate agrees closely with Captain Yule's careful estimate, in his project for a Railway in Rohilkund, of a Cattle Draught line, at Rs 26,500 per mile, but this includes Rs. 2,532 for plant and wagons, which are chargeable to draught rather than construction. It is considerably higher than Mr. Wilson's estimate for a light Railway to be worked by locomotives.—[ED.]

which the standard amount of traffic is conveyed. The cost of repairs upon a road over which 1,872 vehicles pass per day, has, in an average of five years, amounted to £119 14*s*. 9*d*. In order to be on the safe side therefore, I propose to allow £55 per mile for the maintenance of the macadamized line of road in thorough repair.

On the *Railway for Animal power*; an allowance must be made for the wear and tear of rails and sleepers. The actual wear of the road itself will be very much less of course than that of the macadamized road, for the iron rail takes the action of the wheel; if, then, the rails and sleepers are renewed in twenty years, one-twentieth of the whole cost may be provided as an annual charge; and as this cost is £1,700, one-twentieth of that sum will be £85. One-half of the ordinary sum of £30 will be sufficient to cover the cost of other repairs; so that 85 + 15 = £100 will cover the cost of the maintanance of the Railway for animal power.

The maintenance of way upon the *Railway for Steam power* must necessarily include an allowance for the renewal of rails, chairs, &c., and by taking the duration of these at twenty years, as in the Railway for animal power, an advantage will be given to the locomotive line; as the action of the heavy engine, going at the rate of from 20 to 30 miles per hour, must wear away the rail much more rapidly than the light and slow action of the animal power. Assuming then, 5 per cent. to be the annual deterioration of the rail and sleepers, and the cost, as on the Madras line, to be £3000 per mile, the annual charge for renewal of rails and chairs will be £150.

The other items under the head of maintenance are grouped together in the returns, and the cost may be put on an average at about £100 per annum per mile, while the charge for superintendence may be put at £5. The cost of maintenance of way on the steam power line will therefore be as follows:—

	£	*s.*	*d.*
Renewal of Rails and Sleepers, ...	150	0	0
Labor, Ballast, &c., ...	100	0	0
Superintendence, ...	5	0	0
	£225	0	0

The annual charge upon the three descriptions of road under the head of interest of capital, and maintenance of way, will be as shown in the accompanying table:—

	Macadamized Road.			Railroad, Animal power.			Railroad, Steam power.		
	£	s.	d.	£	s.	d.	£	s.	d.
Interest, ...	37	10	0	131	7	0	600	0	0
Maintenance, . .	55	0	0	100	0	0	255	0	0
Total, ..	92	10	0	231	7	0	855	0	0

TRACTION.

Having thus arrived at the cost of constructing the different lines of road, as well as at that of maintaining them in a good state of repair; all that remains to be done is to determine the actual cost of traction upon each. To do this, however, would involve the solution of a variety of very complicated questions. It will be far more simple, therefore, to show, for the ordinary roads and for the existing railroad, the actual charge for the conveyance of passengers and goods. In the case of the *Railway*, the returns show the actual charge for locomotive power under several different heads; while on the *Macadamized Road*, the contract price per passenger or per ton of goods, includes not only the charge for power, but a variety of other items to which I shall allude hereafter.

With reference to the *Railway for Animal power*, I propose to submit a detailed estimate, on a liberal scale, of the cost of working it, as, in this country, I cannot obtain any direct information to guide me.

The cost of conveying goods upon the *ordinary Roads* has been shown to be $3\frac{3}{4}d.$ per ton per mile. This sum includes the interest upon the first cost of the vehicle and the cattle; the maintenance in repair of the vehicle; the maintenance of the cattle, and the hire of the persons employed to drive them; it will also include a premium of insurance upon the carriages and cattle, so that they may be replaced in case of destruction or death, by accident or disease. It also includes or should include, some premium of assurance against the risk incurred as a carrier, who is responsible for the goods under his charge. In addition to all these, it must include such a fair amount of profit as the contractor has a right to expect, besides the simple interest on his capital.

The charge of conveying 1st-class passengers may be put at 6*d.* per mile. This is arrived at by taking the cost of conveyance, by the Transit

Company, from Tripatore to Bangalore, a distance of 80 miles; the transit is capable of accommodating two persons inside, and a servant on the box by the driver. Each person may take 40 lbs. of baggage, and the total charge by the Company is Rs. 40 or 80*s.*, that is 1*s.* per mile, or 6*d.* per each passenger.

A class of passengers analogous to the third-class on the Railway is conveyed to and from places in the vicinity of Madras, at a reasonably rapid rate, in vehicles drawn by bullocks or ponies; each of these vehicles is capable of containing four people, and the rate of charge varies from $2\frac{1}{4}d.$ to 3*d.* per mile for the whole vehicle; taking the largest sum, the cost per mile for each passenger would be $\frac{3}{4}d.$; but it would be safer to estimate the average cost at 1*d.* per mile per passenger, and this may be taken as a fair charge for such work in any part of the Presidency; as the Madras prices are probably in excess of those of the country districts. The cost then of conveying 3,220 first-class and 152,000 second-class passengers, and 32,000 tons of goods, will be as follows:—

		£	s.	d.
3,220 at 6*d.*	=	80	10	0
152,000 at 1*d.*	=	633	6	0
32,000 at $3\frac{3}{4}d.$	=	600	0	0
Total, ..		£1,313	16	0

The returns for the *North West Railway*, for the same amount of traffic exhibit the expenditure under the various heads of classification, as shown in the following table:—

	£	s.	d.
Locomotive Department,	1,906	5	$2\frac{1}{4}$
Fuel,	3,054	12	0
Coaching,	1,259	1	$0\frac{1}{4}$
Tickets,	12	2	$4\frac{1}{2}$
Repair of vehicles,	116	2	$5\frac{3}{4}$
Electric Telegraph,	11	9	0
General charges,	117	6	6
Total, ...	6,476	18	$6\frac{3}{4}$

This sum, divided by 41·25, the length of the line, will give £157 0*s.* $3\frac{3}{4}d.$ as the cost of conveying the whole of this traffic over one mile of Railway. No attempt is made to distinguish the actual cost of conveying

the different classes of passengers or of goods; in fact any attempt of the kind would merely be a matter of guess work. The above may be taken as *facts*, which do not involve any calculation.

I have now, however, to form an estimate of the cost of conveying the same quantity of goods, and the same number of passengers, along a *Railway* by means of *Animal power.*

The number of first-class passengers has been put at 3,220, or roughly, 10 per day, or 5 each way. To convey these, one first-class carriage would be required, which would travel at the rate of 10 miles per hour. It would be drawn by two horses,* and would be capable of accommodating 16 passengers. The distance of 41·25 miles would be divided into five stages, each pair of horses going a stage out and a stage back, or about 16 miles per day; a spare carriage would be required and a spare pair of horses.

The capital expended would be—

		£	£	s.	d.
3 Carriages,	at	250 =	750	0	0
12 Horses,	at	45 =	540	0	0
10 Sets Harness,	at	10 =	100	0	0
	Total,	...	£1,390	0	0

152,000 second-class passengers divided by 365, will give 416 as the daily number conveyed both ways. It will, however, be necessary to reckon upon some extra pressure occasionally; and carriage accommodation must be provided for, say, 240 each way, or 480 altogether. Each carriage will contain 30 passengers, and will be drawn by two horses at the rate of about 6 miles per hour; travelling the same distance as the horses drawing the first-class carriages.

The total number of carriages and horses required for the actual work will, therefore, be 16 carriages, and 80 horses; but it may be as well to estimate for 20 carriages and 100 horses.

The capital expended, then, upon rolling stock and animal power will be—

* Capt. Yule says in his Project, &c., "Draft horses for such a purpose can scarcely be said to exist in India, and we must therefore look to oxen." It would have been well perhaps if this objection so often stated, had been met in the present paper. In the Punjab the Cabul horses, though small are excellent for draught and could be procured well under the estimated price, probably for Rs. 300 each. But the supply is very limited, and in the N. W Provinces, good draught horses, able to do hard work at a fair speed, are unknown. It is to be noted, however, that it is only the *Passenger* traffic which is to be conveyed by horses.—[ED.]

		£	£	s.	d.
20 Carriages,	at	250 =	5,000	0	0
100 Horses,	at	40 =	4,000	0	0
16 Sets Harness,	at	10 =	160	0	0
		Total, ..	£9,160	0	0

32,000 tons of goods may be put at 100 tons per day, or 50 tons each way.

Three tons may be allowed for each truck, and 34, therefore, would be required; each would be drawn by 3 bullocks, 6 extra trucks might be allowed to meet casualties; and a few extra bullocks should be purchased. As the daily journey of a bullock may be put at ten miles, the distance of 41·25 would be divided into four stages; so that 12 bullocks would be required for each truck, $40 \times 12 = 480$, would be in daily use, or say 500 to cover contingencies.

The trucks ought not to cost more than £100 each, and the bullocks £15 the pair.

The capital, therefore, expended upon the rolling stock and animal power for the goods traffic will be—

	£	s.	d.		£	s.	d.
40 Carriages, at	100	0	0	=	4,000	0	0
500 Bullocks, at	7	10	0	=	3,250	0	0
				Total, ...	£7,250	0	0

The total amount of dead and live stock required for the conveyance of passengers and goods along a Railway worked by animal power would be as follows:—

	£	s.	d.
First-class passengers,	1,390	0	0
Second-class do.,	9,160	0	0
Goods,	7,250	0	0
Total, ...	£17,800	0	0

Say £18,000.

The annual charge may be estimated as follows:—

	£		£	s.	d.
Interest upon £18,000 at 5 per cent.,		=	900	0	0
Wear and tear of carriages and repairs, 15 per cent., on	9,750	=	1,462	10	0
Cost of re-placing horses and bullocks, 15 per cent., on	7,790	=	1,168	19	0
Repairs and re-placing harness, 20 per cent., on	260	=	52	0	0

			£		£	s.	d.
Keep of 112 horses, at £24 each,				=	2,688	0	0
Keep of 500 bullocks, at £8 each,				=	4,000	0	0
Hire of 20 coachmen, at £50 each,				=	1,000	0	0
Hire of 166 bullock drivers, at £10 each,				=	1,660	0	0
Repairs of stables, at 5 per cent, on,			2,000	=	100	0	0
Telegraph, &c., charges as on locomotive line,				=	11	9	0
General charges, including Clerks, &c,				=	442	11	0
			Total, ...		£13,485	9	0

This sum, divided by the total distance 41·25 miles, will give the charge per mile for traction £302 12*s.* 10*d*,* and the general comparison between the cost of conveying the standard number of passengers and tons of goods per mile, on the three kinds of road, will be as follows :—

	Macadamized Road			Railroad, Animal power.			Railroad, Steam power.		
	£	s.	d.	£	s.	d	£	s.	d.
Interest,	37	10	0	131	7	6	600	0	0
Maintenance,	55	0	0	100	0	0	255	0	0
Cost of working,	1,313	16	0	302	12	10	157	0	3¾
Total,	1,406	6	0	534	0	0	1,012	0	3¾

I have in calculating the cost of working the Animal power Railway, made allowances for a variety of extra expenses; and I feel confident that the sum shown in the above table will be ample to cover the whole cost of working the line, and of paying an interest of 5 per cent., upon the capital expended. Under these circumstances, it is evident that, until upon any given line of road the amount of traffic very far exceeds that which passed over the North West line of railroad in the first half of 1863, it will be

* Capt. Yule's estimate per mile for a Cattle Draught line, is only Rs 1,317, of which Rs. 140 are charged to maintenance of way (not included above); Rs. 430, to wear and tear of rolling stock; Rs. 374 for hire of Cattle, and the same for Establishment; the cost per ton per mile being reckoned at 0·7 annas. Mr Hardy Wells in his Report on the same line, estimated the Draught expenses per mile of a Horse Railway at Rs 5,650, and of a Bullock line at Rs. 6,361.

The great difference in this last estimate is in the number of animals estimated for, 2,000 horses or 4,000 bullocks for a line of 110 miles in length, being double the number set down in the present estimate for a similar length. Mr. Wells' calculation is for 105,000 tons of goods, and 224,000 passengers, yearly; each passenger is reckoned at 3 mds. = 240 lbs, probably to include his baggage. The cost, therefore, of haulage per ton mile, would be 0·7 annas for horses, and 0·8 annas for bullocks. It is to be noted, however, that these estimates do not include any charge for the interest on the dead and live stock, which is probably considered to form a part of the whole capital sunk. In the present estimate, deducting this item, and dividing the annual cost by the traffic, the cost per ton mile will be 0·75 annas, showing a striking agreement between the three estimates, considering that all are worked out on totally different data.—[ED.]

far cheaper to employ animal power than steam, in the movement of passengers and goods.

It remains to be seen what charge it will be necessary to impose upon the traffic, in order to cover the whole of the charges upon the road; namely, interest of capital, maintenance of way, and cost of transport. An analysis of the cost of conveying the different descriptions of traffic will show that the following is pretty nearly the ratio of the outlay upon each

First-class Passenger,	·066
Second class do.	·430
Goods,	504

and if the whole charge of £534 per mile be divided in these proportions between the different heads of traffic, the charge upon the first-class passenger must be such as would return £35 4*s.* 10½*d* ; that upon the second-class, such as would yield £229 12*s.* 4¾*d.*, and that upon goods such as would give £269 2*s.* 8¾*d.* Now the charge of £35 4*s* 10½*d.*, divided by the number of first-class passengers, viz., 3,220, would give 2·6 pence as the charge per head per mile. In the same way, £229 12*s.* 4¼*d.*, divided by 152,000, the number of second-class passengers, would give 1·38 farthings, as the exact charge per head per mile; while £269 2*s.* 8¾*d.*, divided by 32,000, would give 2·018 pence as the charge per ton per mile. A first-class passenger, however, might very fairly be charged at the rate of 3 pence per mile, and a second-class at a half-penny, while the charge for goods might be put at 1½*d.* per ton per mile; at these rates, with the standard amount of traffic, the gross returns would be £556 18*s.* 4*d.*, or £22 18*s.* in excess of the amount shown above to be sufficient to cover the interest of capital, maintenance of way, and cost of conveyance. Provision, however, has been made for the conveyance of upwards of 11,000 first-class passengers, 190,000 second-class, and 44,000 tons of goods without any extra charge; and should the traffic increase to this extent, the returns at the rates mentioned above, would be—

	£	*s.*	*d.*
First-class Passengers,	137	10	0
Second-class do.,	395	16	8
Goods,	275	0	0
Total, ...	£808	6	8

And the profit upon the capital expended (which, at the rate of £2,627 per mile of road for construction, and £18,000 ÷ 41·25 or £436 for live

and dead stock, would amount to £3,063), would not be less than 13 per cent.

The fair conclusion to be drawn from what has been stated is, that with an amount of traffic larger than that which is likely to pass over most of the feeders of the Railways now in progress, a Railway worked by Animal Power would be a much cheaper mode of communication than either a Macadamized Road, or a Railway worked by Steam Power.

If, however, this would be the case when the traffic is already heavy upon the line of road, the advantages of animal power over steam would be still more marked when the traffic is comparatively light, and requires to be developed gradually. A Railway worked by steam must be provided with engines of power sufficient to drag the largest train over the steepest gradient on a line: and though the consumption of fuel is, to a certain extent, proportioned to the load the engine has to convey, yet, as this load is in very great measure composed of the dead or unprofitable weight of engines and carriages, the saving of fuel is not very great; while the other items which make up the working expenses, are in great measure independent of the load, and form a mileage charge.

With a Railway worked by animal power the case is different; here the power required is strictly in proportion to the load; no more horses or bullocks are kept than will be sufficient to meet the demands of the public for conveyance; and if these demands are casual or intermittent, arrangements can easily be made to meet the casual portion of the demand without the expenditure of capital, or the imposition of a permanent charge upon the promoters of the line of Railway. Again, the power of a locomotive engine must be proportioned to the maximum effort it has to make; that is, it must be competent to overcome the steepest gradient in the line with a full train behind it; it must, therefore, have an amount of power more than sufficient to do the work of the more level portions of the line; in fact, it is necessary to have an engine of 100 horse power, which it might have to exert for a mile or two; while an engine of 50 horse power would be amply sufficient to do the remainder of the work.

This is not the case with a Railway worked by animal power. If there be a hill too steep to be surmounted by carriage drawn by the ordinary team of horses or bullocks, the simple plan is to have a spare pair at the bottom to help the carriages over the hill. This, however, will seldom be necessary with horse teams; for a horse has a reserve of muscular energy,

which enables him to exercise for a short time, a much greater amount of power than is wanted for his ordinary work.

It is not, of course, probable, that the ratio between the passengers and goods traffic, which I have assumed as the standard for calculation, will obtain upon ordinary branch lines. The passengers traffic will be less than the standard, while the goods traffic will exceed it; looking, however, to the fact that I have estimated the cost of the rolling stock and the animal power, at a high figure, and have been very easy in my demands upon the animal power, it is more than probable that, when worked by a Company or an individual, the charge of $1\frac{1}{2}d.$ per ton per mile will be found sufficient to cover all expenses, and to give an interest upon the capital expended of at least 5 per cent.

I think, then, that I am justified in applying to by far the larger number of branches from the main line of Railway in India, the following conclusions:—

1st. That the cost of transport upon a Macadamized Road is largely in excess of that upon a Railroad, whether such railroad be worked by Animal or Steam power.

2nd. That the actual cost of Steam power is much less than that of Animal power upon railroads, but that this cheapness is, with a limited amount of traffic, more than compensated for by the increased cost of construction and maintenance of the railroad worked by steam.

3rd. That the circumstances of the country are not such as to admit of so large a development of traffic upon the branch lines of railroad as would compensate, by the saving in the cost of motive power, for the increased charge under the heads of interest of capital, and maintenance of way, consequent upon the adaptation of the road for Steam power.

4th. That, as a general rule, it would be far cheaper, and, therefore, more advantageous in every respect to construct the branch lines of Railway with a view to their being worked by Animal power.

W. T. Denison.

No. LXXVII.

DHARWAR BRIDGES.

By J. Hart, Esq., C.E.

The Yangul Bridge* is the last of several subscription Bridges constructed over the Bunnehulla; a river which runs through the centre of the chief black soil plain of the Dharwar district.

The characteristics of this river are peculiar. Rising in the west, within the range of the south-west monsoon, it is subject to high floods during the months of June, July, August, and September; while, being fed by large tributaries from the east, it is liable to considerable freshes during most of the other months in which thunder-storms prevail.

Its waters are brackish, but by sinking pits in its bed, fresh water is obtained within a few feet of the salt.

Its banks are of black soil, of the most unstable character, giving way with the slighest set of the current against them, and then presenting steep scarps, so that the road slopes at its crossings are most difficult to maintain.

Its bed, consisting of silt and sand, overlying clay mixed with kunkur, abounds in quick sand during the rains; so that the crossing of this river was at all times a matter of anxiety to travellers.

This river, therefore, from several causes, formed a serious impediment to all communication between the villages on both sides for at least six months of the year; and this was so acutely felt that the inhabitants of the Hooblee, Nowlgoond, Dumbul, and Roan Talookas, subscribed to

* This bridge (the Yangul) is distant from Dharwar 42 miles, being nearly double that of any of the other bridges.

build bridges along its course. In this they were assisted by Government, who supplemented their subscriptions by a "grant in aid." Bridges were thus built at Seergoopee, Hebsoor, Purdessoor, and Yangul.

The design of all these bridges is similar; being long timber piles driven into the river bed at short intervals to form the piers, on which whole logs are laid longitudinally as girders, and immediately on these, the road planking and material.

The piles of the bridges average 10 to 12 inches square, being hooped with a 28 ℔ ring, and shod or pointed, with a V shaped strap of, 3 × ½-inch, iron.

The nuts of the bolts used in these bridges are rivetted instead of being screwed on the shank, this former being found to be the more economical method.

The design adopted has been influenced by several considerations; the character of the bed and banks of the river; the ease with which large timber was procurable from the adjoining forests of North Canara, and the want of skilled labor and trained superintendence to carry out any very elaborate construction.

There is little to interest, therefore, in the structures themselves, but I venture to bring them forward for the purpose of giving some of the data connected with them, which may be of use to any one wishing to construct similar rude but effective bridges; and also, to enable me to describe the pile engine* used in building them. I am indebted to a drawing by Captain Playfair for the sketch of it, which I send; it will be of interest to those who do not know of the make-shifts to which Indian Engineers are often driven for plant.

The Pile Engine, which does not differ materially in principle from those ordinarily used, was constructed, I believe, by Captain Playfair, aided by Dr. Forbes, who had at his command the mechanical skill and resources of the Dharwar Cotton Gin Factory. It is roughly and economically built; and is well suited to the work it has to do, and to the workpeople for whose use it is intended.

Its chief features are an upright, or standard, formed by two vertical pieces, between the faces of which the monkey works, two longitudinal pieces, into which the foot of this standard is morticed, and to which it is stayed at the back; a frame, or platform, from which the above is hung,

* A working model of it was, I believe, sent to the Lahore Exhibition by Dr. Forbes.

and on which it runs transversely, motion being obtained by small rollers working on the upper side of the cross girders of the platform.

The Platform itself, on four large wheels, runs along a Tramway. The Ram is formed of an old gun, taken from the Fort of Noorgoond, after the capture of that place. The gun was sheared off at the breech, and a "lug" leaded into its muzzle, gives the means of lifting it by a pair of nippers.

These nippers, as well as the ram, slide in grooves in the faces of the standard, and on reaching the height of the jaws, the ram is released in the usual manner.

The weight of the ram is 680 ℔s, and with the maximum fall of 18 feet, has a momentum of about 23,120 ℔s or 10·3 tons. Five men are required to work the engine; viz., four at the winch, and one on the top, to facilitate the descent of the nipper after the ram; this is necessary on account of the friction of the rope in the two sets of blocks; besides these, four men are required for reliefs.

In constructing one of these timber bridges the first step is to erect a temporary scaffold, with a tramway for the pile engine to run on; and since the piles when driven are to be of the full height, in order that the girders of the bridge may rest immediately on their heads, the height of this scaffold must be fully as great as that of the intended bridge. It must also be somewhat wider to allow of the lateral motion of the standard, with ram, over the heads of the piles.

The scaffold is constructed with stout poles, fastened in old telegraph post sockets, or shoes. The sockets are screwed into the bed of the river as deep as they will readily go, a hole being first dug a few feet into the sand to receive them. On the top of these poles, which are in pairs, are fastened light cross pieces to carry the tramway girders, along which, guided by a slip of wood, run the wheels of the pile engine frame. Thus, the engine is enabled to command the whole length of the intended bridge, while the transverse motion of the standard of the engine on its own frame, serves the same end as regards the breadth of the structure.

The Pile Engine being secured in position by wedges over the site of one of these piles, and a hole being dug to receive the point, the pile is raised into position by help of the windlass and blocks of the engine; and the operation of driving begins.

It is difficult to keep these very long piles from taking a set, or drift; this is prevented as much as possible by stay ropes run out, counter to any

such tendency which may appear while they are being driven; there are, however, few of the bridges in which some of the piles are not considerably out of plumb.

The piles receive, when nearly driven, a blow every four or five minutes, about one and a half minutes being consumed in raising the monkey, and the rest of the time in getting down the nippers. A pile is driven each day, which makes the calculated cost of driving one to be about Rs. 3 or 4.

The rule observed as to the depth to which the piles are to be driven seems rather indefinite, they are driven an average depth of 12 feet into the bed, or until they refuse to drive further, and begin to split at the head.*

Diagonal bracing, transversely between the piles, as shown in the section, is not always to be recommended, as it may cause the accumulation of great quantities of brushwood in the time of flood. Moorum covering is also objectionable, on account of the rapidity with which the planking under it decays. I observed the following instance of its effect the other day in the Hebsoor bridge. That bridge is covered with moorum, and I find by examination that its planking is quite rotten, while that of another timber bridge near it, not *moorumed*, is still quite sound. The age of the former is two years, of the latter four, which makes the comparison still more striking. This defective arrangement is avoided in the Yangul bridge.

It seems to me that the only disadvantages of bare planking are danger of fire, inconvenience to horsed vehicles from the noise, and to cattle, from its slipperiness in the rains; but, these are not worthy of being considered when the destruction of such an expensive item as planking is at stake. It is a question whether it would not be better, and also in the end cheaper, to use transverse joists laid over the longitudinal road girders, to carry the planking; the last might then be made a little lighter. This is a point however, which the experience of a few years will probably decide.

Slight improvements might also be made in the pile engine, the most obvious of which is the substitution of a crab winch with a single pulley at the top, for the wooden winch and two sets of blocks. This would effect a considerable saving, in *time*, because of the facility with which

* The mistrie in charge says, that when this occurs, the pile sinks about ¼ to ½ an inch with each blow.

the nippers would then follow the ram; in *labor*, because under this arrangement the man placed on the standard to free the ropes, would not be required; in *height* of standard, because the space taken up by the double blocks would be made available.

The ram might also be heavier, and the fall less, which would decrease somewhat the liability of the heads of the piles to split; and, I think, some of the scantlings of the frame might be reduced with advantage.

The quantities and cost of the Yangui bridge, taken from the work accounts are as follows:—

BRIDGE.

		Rs.
r. ft.		
656	Erecting tramway for pile engine, nearly all labor, @ ·75 each, ...	492
988	Piles driven into bed (labor), @ 1·69 each, ...	1,679
c. ft.		
1,861	Timber in piles, including all work except driving, @ 2·92 each,	5,452
3,290	„ girders, planking, and standrail, @ 7·3 each, ...	24,020
	Total, Bridge, ...	31,643

APPROACHES, &c.

c. ft.		
6,320	Excavation of foundations, @ 1·0 per 100, ...	65
2,992	Dry stone rubble, @ 19 0 each, ...	588
2,73,099	Earthwork, @ 375 per 100, ...	1,172
11,014	Gravelling surface of road, @ 1·0 per 100, ...	126
	Total, Approaches, ...	1,951
	Grand Total, ...	33,594

If to the rate for driving piles, be added the contingent cost of the tramway, the cost of driving them per foot will be in these bridges, Rs. 2-2, and the cost of each pier be Rs. 508.

The following is a table of the principal dimensions, cost, &c., of the several timber bridges constructed in the Dharwar district, on the principle mentioned in the foregoing pages.

Name and Description of Bridges and date of Construction.	Length.	Breadth out to out	Greatest over bed	Cubic feet of Timber.	Cost of Timber.	Cost per Foot of Timber-work only.	Total Cost of Bridge.	Total rate per foot of Bridge.	Remarks.
SEERGOOPEE, 9 bays of 10 feet span, 1862.	144	22		4,230	2,243	15·5	7,116	49 4	Rates—Wood, 10 as. per c ft.; coolie, 2 as. per day; carpenter, 8 as. per day.
HEBSOOR, 15 bays of 16 feet span, 1862.	240	22	21	6,083	3,508	14 6	11,440	47 6	Rates—Wood, 10 as per c. ft; coolie, 2 as per day; carpenter, 8 as. per day.
PURDESSOOR, 15 bays of 16 feet span, 1862.	240	22	23	7,664	5,607	23·3	13,764	57·3	Rates—Wood, 10 as per c. ft., coolie, 2 as. per day; carpenter, 8 as. per day.
YANGUL, 8 bays of 20 and 6 bays of 17 ft. span, 1864.	263	22	24	6,174*	11,406	43·3	22,690	86·2	Rates—Wood, Rs. 2-8 to 3-8; coolie, $4\frac{1}{2}$ as per day; carpenter, 12 as. per day.

* Besides the timber shown in this item, there was some of that of the pile engine, tramway, used up in the bridge, which makes a slight confusion in the timber accounts.

J. HART, DHARWAR.

No. LXXVIII.

KOORUM FRONTIER OUTPOST.

Estimate framed by Lieut. J. Browne, *Exec. Engineer, Kohat Division, of the probable Expense of Building a New Outpost at Koorum, Bunnoo Frontier.*

The proposed post is adapted for a garrison of fifteen sabres and fourteen bayonets; but could, if necessary, accommodate a larger number. It consists of a Square with Bastions at two opposite corners, the bastion facing the hills being provided with a Watch Tower 30 feet in height. The terreplein of the bastions is raised 5 feet above the general level of the ground, a step is provided along the walls so as to ease the weight of the defenders manning the loop-holes from the roofs of the barracks. The latter are 10 feet in width and 9 feet high in the clear; a small tank 10 × 10 feet and 2 feet deep, is provided in the corner to enable the garrison always to have a good store of water. The horse lines leave a clear space of 15 feet on all sides between them and the barracks. The walls are 18 feet in height, which is rendered necessary by the post being unprovided with a ditch. Drains of rubble masonry, 2 feet wide by 6 inches deep, run along the front of the barracks and converge in cross drains which carry the water out of the fort.

Specification.—The walls of the fort to be of pucka masonry with the exception of the step, 16 inches wide and 11 feet high, which runs along the inner face of the walls. The tower and walls of the barracks to be of kucha masonry. The walls, tower, &c., to be duly plastered and gobured,

and the barracks whitewashed. The tank and drain to be of rubble masonry well allowed to dry before being wetted. The gate to be 10 feet in width, rough hewn, and squared on the diagonal.

Abstract of Expense.

		R.	A.	P.
c. ft.				
41,000	Pucka work, at Rs. 2 per 100, ...	820	0	0
26,774	Kucha masonry, at Rs. 3 per 100, ...	803	0	0
s. ft.				
3,068	Roofing, at Rs. 10, ...	307	0	0
32,824	Pucka plaster, at Rs. 0-8-0, ...	164	0	0
3,391	Whitewash, at Rs. 0-5-0, ...	11	0	0
c. ft.				
25,500	Earthwork, at Rs. 3 per 1000, ...	77	0	0
1,576	Rubble, at Rs. 10, per 100, ...	158	0	0
100	Gateway, at Rs. 1, per foot, ...	100	0	0
1	20-feet Ladder, at Rs. 5, ...	5	0	0
	Total, ...	2,445	0	0
	Add Contingencies, at 5 per cent., ...	122	0	0
	Total Rs., ...	2,567	0	0

Note by Editor.

Outposts on much the same plan as the above (except that many have one bastion only) have been built all along the Trans-Indus Frontier, close to the foot of the hills, and at distances of 10 to 15 miles apart, forming thus a chain of posts connected by a road extending from Scinde to Kohat, a distance of some 300 miles; guarding the passes into the low country and effectually checking the raids of the Hill Tribes. It is in this manner that a wild and lawless frontier has been gradually brought into subjection and quietness, which under its former native rulers, was a perpetual thorn in their side. Daily patrols are established between the posts so that early information is received of any raid in the border, and the cavalry can then sally out, leaving the infantry in charge of the post. The tower serves both as a look-out and as a citadel to the small force of infantry, which could thus defend itself and the post, in case of attack during the absence of the cavalry on service; a similar plan of defence for the N. E. Frontier might perhaps be equally successful.

No. LXXIX.

ATTOCK CHURCH—PUNJAB.

Design and Built by W. B. Harington, Esq., *Executive Engineer, Peshawur.*

Report.—In November 1860, an estimate was called for to provide Church accommodation at Attock for the usual garrison, but capable of enlargement if required at any future day. A plan for a Church to seat 150 was accordingly submitted in July of the following year, but, until brought forward again in the Budget of 1862-63, the project remained in abeyance

A sum of Rs. 15,000 has now been allotted to the work, with a view to erecting a building of some architectural pretension, which the fine site, enabling it to be seen from some distance on all sides, seems justly to demand.

The design now submitted is for a Church calculated to seat 250 persons, being about 25 in excess of the present garrison, including the residents in the fort and "serai."

Specification.—The building to consist of a Nave (61′ × 22′) with north Transept (21′ × 12′) and side Aisles, and a Chancel (16′ × 14′).

A Tower (10′ × 10′ internally), and rising to a total height of 74 feet, is placed on the east of the transept, at the angle formed by it with the nave, and this with a porch (11′ × 9′) opposite to it, completes the design.

The ground-floor of the tower is appropriated to the Vestry, and the first storey can serve, if required, as an Organ loft, since it opens into the nave, and can be approached by the steps and stair-case on the north

face of the tower, without going through the lower apartment. The arrangement and grouping will however be sufficiently explained by the accompanying plans.

In construction, the building throughout will be of the most solid and substantial character. The *masonry*, for the most part, to be of rough-dressed stone of the best description to be found in the neighbourhood, brick being used only in the columns of the Nave, the arch mouldings, and such other portions of the structure as may seem in process of contruction advisable. All external and exposed work to be carefully finished, and plaster to be given to the interior only.

The *flooring* to be of tiles (9 × 9 inches) red and gray laid diagonally over brick-on-edge, the upper floors of the Tower to be $1\frac{1}{2}$-inch planking over joists 9 × 6 inches.

The *roof* of the Nave, Chancel, and Transept, to consist of tiles (or shingles) over planking, over rafters and purlins resting on substantial trusses, placed $11\frac{1}{2}$ feet apart from centre to centre, corresponding to the pillars of the nave; one truss of the same pattern being given to the transept and chancel, respectively. The roof covering of the side Aisles to be similar to that of the nave, but with flying arches springing from the aisle walls in place of trusses. The pitch of the nave, transept, and chancel roof to be 51°, and of the side aisles 21°.

The Tower to be covered by a timber frame-work, sheeted with zinc, and terminating with an iron finial, with a standard at each angle; one being a lightning conductor, and having a greater elevation than the rest. The rod should pass to the ground in the angle formed by the two buttresses at the south-east corner of the tower.

The *doors* to be battened, with massive ornamental hinges, and *hung*; no chowkuts being used.

The *windows* to be glazed diagonally, and stained glass to be introduced if funds allow, giving the preference to the east and then to the west window.

Sittings (of stained deodar) to be provided for 250 persons, the benches being so arranged as to occupy the whole of the nave, the north and south aisles forming the means of ingress and exit. The remainder of the *fittings*, comprising pulpit, reading desk, and chancel rail, to be of sissoo or walnut wood.

The *punkahs* to consist of deep and full fringes, weighted with lead, and

attached to ornamental bars of sissoo, suspended from the iron ties of the roof-trusses.

The *font* to be of stone, carved at Delhi.

It is believed that in the following abstract, ample rates have been allowed to ensure work of the very best description, especially when it is considered that (as regards the masonry) no openings have been deducted. In explanation of the probable total cost, it should be noted that *at least* Rs. 1,000 will be forthcoming by private subscription, in addition to the Government grant of Rs. 15,000.

Abstract of Cost.

		R.	A.	P.
c. ft.				
42,477 5	Masonry, at Rs. 20, per 100, ...	8,495	8	0
r. ft.				
484	Cornice, at Rs. 25, per 100, ...	121	0	0
s. ft.				
3,020	Tiled flooring, at Rs. 12, per 100, ...	362	6	5
400	Plank flooring, at Rs. 50, per 100, ...	200	0	0
3,999	Trussed roofing, at Rs. 80, per 100, ...	3,199	3	2
759	Pent roofing, at Rs. 50, per 100, ...	379	8	0
560	Zinc roofing, at Rs. 100, „	560	0	0
231	Doors, at Rs. 1-8, per foot, ...	346	8	0
332	Windows, at Rs. 1-4, per foot, ...	415	0	0
250	Sittings, at Rs. 3, each, ...	750	0	0
1	Pulpit, at Rs. 100, ...	100	0	0
1	Reading desk, at Rs. 30, ...	30	0	0
22	Punkahs, at Rs. 10, each, ...	220	0	0
1	Chancel rail, at Rs. 50, ...	50	0	0
1	Font, at Rs. 100, ...	100	0	0
	Total, ...	15,329	1	7
	Contingencies at 5 per cent. Rs., ...	766	7	3
	Grand Total, Rs., ...	16,096	0	0

W. B. Harington,
Offg. Ex. Engineer.

Peshawur,
November 1862.

TAHRCLE, P. W. DEPARTMENT, IN OR ABOUT THE MONTH OF MAY, 1864.

	Goruckpoor.	Jhansi.	Mhow.	Nusseerabad.	Bareilly.	Gwalior.	REMARKS
Mistrie maso	0 0	15 0 0	30 0 0	30 0 0	...	15 0 0	
Skilled workn	7 0	0 4 0	8 to 13*a*	0 8 0	...	0 5 0	
Ordinary do.,	6 0	0 3 0	5 to 7*a*.	0 5 0	...	0 3 0	
Mistrie brick	0 0	12 0 0	30 0 0	30 0 0	10 0 0	12 0 0	
Skilled workn	6 0	0 4 0	8 to 13*a*	0 7 0	0 5 0	0 5 0	
Ordinary do ,	4 0	0 3 0	5 to 7*a*.	0 5 0	0 3 6	0 3 0	
Mistrie carpe	0 0	15 0 0	30 0 0	30 0 0	12 0 0	15 0 0	
Skilled work	*a*. to 1*r*	0 5 0	0 8 0	0 8 0	0 5 0	0 5 0	
Ordinary do.	5 0	0 3 6	0 6 0	0 5 0	0 3 6	0 3 0	
Mistrie smith	0 0	12 0 0	30 0 0	30 0 0	10 0 0	12 0 0	
Skilled work	*a*. to 1*r*	0 4 0	0 8 0	0 8 0	0 4 0	0 4 0	
Ordinary do.,	4 0	0 3 0	0 5 0	0 6 0	0 3 0	0 3 0	
	8 0	0 4 0	0 6 0	0 4 0	0 0 6	0 6 0	
	3 0	0 3 0	0 4 0	0 3 0	0 2 0	0 3 0	
	2 0	0 2 6	0 4 0	0 3 0	0 2 6	0 3 0	
Beldar, ...	2 0	0 2 6	0 4 0	0 3 6	0 2 0	0 2 6	
Mate coolie,	2 0	0 2 0	0 3 6	0 3 0	0 2 0	0 2 0	
Coolie, ...	1 6	0 1 6	0 2 0	0 2 0	0 1 6	0 1 6	
Boulders or u	...	6 4 0	8 10 0	...	...	...	
Bricks (best)	0 0	7 0 0	7 0 0	...	7 8 0	5 0 0	
Ditto (second	0 0	...	5 0 0	...	...	...	
Ditto (best),	0 0	...	...	4 4 0	...	...	
Ditto (second	0 0	...	...	...	...	...	
Small native	...	...	...	...	0 12 0	1 0 0	
Tiles, commo	0 0	4 0 0	2 12 0	1 8 0	1 8 0	1 4 0	
" Goodw	0 0	...	...	...	11 4 0	...	
Flooring tiles	0 0	...	..	...	...	...	
Lime, best ku	to 35	7 0 0	10 to 20	12 to 20	20 0 0	10 0 0	

The Instruments used in Captain (afterwards Colonel) Lambton's operations were a 36-inch Theodolite, by Cary; an 18-inch repeating Theodolite, by the same maker; a 5-foot Zenith Sector, by Ramsden; two Steel Chains, by the same maker; a standard Brass Scale, by Cary; and several small theodolites by different makers, for minor purposes. These instruments were the finest that the state of art at the commencement of this century could produce; but the great theodolite received an injury in the year 1808, while it was being hoisted to the summit of a lofty pagoda in Tanjore. This injury was repaired by Colonel Lambton himself, who, to the duties of astronomer and surveyor, had, throughout his operations, to combine those of a mathematical instrument maker. In Europe great facilities exist for repairing and preserving instruments, but in judging of geodetical operations in India, more particularly in Colonel Lambton's time, allowances must be made for want of aid in every part of the work.

On the 10th April, 1802, the work was commenced by the measurement of a Base Line of 40006 4 feet, near Saint Thomas's Mount, Madras. Captain Lambton used a chain similar to that already employed by General Roy on the Ordnance Survey in England; it was made of blistered steel, in 40 links of $2\frac{1}{2}$ feet each. The chain was laid in coffers or long boxes, supported on stout pickets driven into the ground, and their heads dressed even by means of a telescope. At one end of the chain was the draw-post, to the head of which the near end of the chain being fastened, could be moved a little backwards or forwards by means of a finger screw. Near the handle of the chain, and at the point where its measuring length was supposed to commence, there was a brass scale, with divisions, which was fixed to the head of another picket, distinct both from the draw-post and from those supporting the coffers. This scale could, by means of a screw, be moved backwards and forwards on the head of the post, till it coincided with the mark on the chain. A similar arrangement was made at the other end, but the handle of the chain, instead of being firmly attached to the *weigh* post, as it was called, had a rope passing over a pulley: and to this rope was appended a weight of 28 lbs. to keep the chain stretched. This arrangement, it is obvious, enabled the measurer to move his chain backwards or forwards with the greatest nicety, and when satisfied that it was correctly placed, to keep it

there perfectly steady; while by means of the registers, he marked exactly the places of the two extremities of the chain. The chain was then taken forward, and the near end being adjusted to the scale which had before marked the fore end, a new chain's length was laid off, and so on till the base was finished. Thermometers were placed in the coffers to determine the temperature of the chain; and the rate of expansion being previously determined by experiment, the necessary corrections were made for the varying temperature of the measurement. The quantity of this correction had been found by Colonels Williams and Mudge, to be on 100 feet, ·0075 inch for every 1° of Fahrenheit; but Captain Lambton, by some experiments performed with the chain itself, in October 1800, found ·00725, which quantity he applied as the correction of his measurement.

Besides the original chain a second was obtained from England, exactly similar. Its length had been fixed in the temperature of 50°. This chain was preserved as the standard, and to its indications were reduced all the measurements made with the other. The length of this standard chain was afterwards corrected for a trifling discrepancy detected by Captain Kater, when comparing standards at home, previously to establishing a uniform system of weights and measures.

In May, 1804, a base of verification of 39793 7 feet was measured by Lieutenant Warren, Captain Lambton's Assistant, near Bangalore; and though the distance was 160 miles nearly, the computed and measured lengths of this base, differed only 3·7 inches, or about half an inch in a mile: a proof of the great care and accuracy with which the work had been conducted. This base was adopted for the origin of the great Indian Arc series. It is hardly necessary to say that the steel chain is now entirely superseded by Colonel Colby's apparatus of Compensation Bars.

From this base a series of triangles was carried across the peninsula to the opposite coast, and a meridional series also commenced on a meridian about 35 miles west of Madras, which was subsequently abandoned for the meridian of Dodagontah further to the west, and on which the Great Indian Arc series was gradually established from Cape Comorin up to latitude 29½° N.; being the largest Arc yet measured on the earth's surface.

In his early operations Colonel Lambton was assisted by Lieutenant

Warren, of the 33rd, and Captain Kater, of the 12th, Foot. The first named officer belonged to the ancient noblesse of France, to which country he returned after the peace. His stay with Colonel Lambton was of short duration, as he was, at a very early period of the work, appointed to the charge of the Madras Observatory. Captain Kater's health having failed, obliged him to quit the department. This officer afterwards acquired an European reputation as a scientific man, having become a member of almost every academy in Europe, been employed on every business of national research, appointed a member of the Board of Longitude, and finally elected vice-president of the Royal Society. Thus it appears that, during the greater portion of his career, Colonel Lambton worked nearly single handed in the extensive and arduous operations which he carried on, amidst the formidable trials and obstacles that the baneful nature of the climate and the want of resources in the country everywhere presented.

It must also be borne in mind, that for a long period these operations were frequently interrupted by the disturbed political condition of the country, which was often the scene of warlike operations; for it was not until the Marquis of Hastings destroyed the Pindaree confederacies in 1818, that the Peninsula and Dekhan settled down into repose. The mysterious character of the instruments and operations, as well as the planting of flags and signals, have always more or less awakened the apprehensions or excited the jealousy of the native princes; it requires, therefore, no ordinary tact, firmness, and patience, on the part of the head of the department to conciliate good will.

Shortly after the commencement of his labors, Colonel Lambton was called on to demonstrate the utility of his work. It was asserted that surveys on an Astronomical basis would be equally accurate, and more economical than Geodetical operations. The futility of these views was ably exposed by the Colonel, and being supported by the Astronomer Royal of the day, (the Rev. N. Maskelyne,) all open opposition was withdrawn, and Major Rennell, who was the chief advocate of the astronomical basis, afterwards concurred in the trigonometrical system.* As this view of the subject has been confirmed by the prac-

* Colonel Lambton's operations detected an error of no less a quantity than 40 miles in the breadth of the Peninsula, as previously laid down astronomically in the way Major Rennell proposed. All the principal places on the old maps, which had been fixed astronomically, were found

tical testimony of every nation in Europe, and the importance of trigonometrical operations is now universally admitted by all practical scientific men as the only trustworthy basis for extensive national surveys, it is unnecessary to discuss the first principles any further in this place, and they are only adverted to in illustration of the formidable prejudices the trigonometrical survey in India has all along had to contend with. The Hon'ble the Court of Directors, however, when once convinced of the important practical utility of the work, have ever since continued its firm and powerful supporters, and in the words of the "Edinburgh Review," "their liberal and enlarged views cannot be too highly commended."

Colonel Lambton remained at his post till his death, which occurred on the 20th January 1823, at the age of 70, at Hingun ghât, about 50 miles from the city of Nagpore, in the Dekhan.

The professional account of Colonel Lambton's labors is given in the first five volumes of the General Report, which are deposited at the India House in manuscript. Condensed accounts of the more scientific part of his operations have been from time to time published. (*See* Vols. VII., VIII., X., XII., and XIII., *Asiatic Researches*.)

Colonel Lambton, between the years 1802 and 1815, covered the whole country as high as 18° latitude with a net work of triangles, whereby the Peninsula was completed from Goa on the west to Masulipatam on the east, with all the interior country from Cape Comorin to the southern boundaries of the Nizam's and Mahratta territories. Subsequent to this achievement, the great Arc triangulation was extended nearly to Takal Khera, in latitude 21° 6′. The greater part of the Nizam's eastern territories were triangulated by meridional series between the Kistnah and Godavery, and considerable progress was made in the longitudinal series from the Beder base towards Bombay. All these operations are described in minute detail in the volumes of the General Report, at the India House.

The area comprised by the whole of the operations prosecuted during the time Colonel Lambton was superintendent, aggregates 165,342 square miles. The expense incurred amounted to 8,35,377 Rs. Consequently, the rate at which the triangulations have been executed

considerably out of position. For example, Arcot was out 10 miles, and Hydrabad no less than 11′ in latitude and 32′ in longtitude.

averages Rs. 5-0-10, or less than 10s. per square mile; which cannot but be considered remarkably cheap.

From the circumstance of Colonel Lambton's operations having commenced in Southern India arises the great superiority of the maps of the Madras Presidency; the atlas sheets whereof, published by order of the Hon'ble East India Company, are nearly complete. This part of India was surveyed in detail upon the basis of Colonel Lambton's operations, and on a scale of 1 mile per inch, by the officers and sub-assistants trained at the military surveying schools.

In October 1817, the Marquis of Hastings, impressed with a well-founded conviction of the important utility of the Trigonometrical Survey, resolved to transfer the control over its operations to the Supreme Government of India; and further, in consideration of Colonel Lambton's increasing age and infirmities, which were little fitted to encounter the laborious exertions, corporeal and mental, which such a task demands, selected Captain (now Colonel) Everest, as eminently fitted by mathematical attainments and practical skill to assist the superintendent, and eventually become his successor.

Captain Everest joined the Colonel as chief assistant in the latter end of 1813, and was employed, in the first instance, in the triangulation of the eastern parts of the Nizam's dominions, where in consequence of the extremely unhealthy character of the country, he twice fell a victim to jungle fever, and eventually was ordered to the Cape of Good Hope for the recovery of his health. While at the Cape, Captain Everest employed his leisure in investigating the circumstances appertaining to the Abbé de la Caillé's arc, which formed the subject of a valuable paper, published in the first volume of the Astronomical Society's Transactions.

On his return to duty Captain Everest was deputed on a longitudinal series of the great triangles emanating from the Beder Base line, and intended to connect Bombay. He was engaged on this important work at the time of Colonel Lambton's death, by which event he succeeded to the office of Superintendent, and immediately proceeded to concentrate the resources at his disposal on the extension of the Great Arc series, which after many difficulties was at length carried up to latitude 24°, where a Base line was measured at Seronj.

An account of these operations is given in detail in the fifth and

sixth volumes of the General Report, deposited at the India House. All the scientific portion relating to the fifth section of the great Indian Arc was further published by order of the Hon'ble East India Company, in the year 1830.

After the termination of the Sironj base line, Captain Everest proceeded to England for the recovery of his health; and as there was no person in India competent to succeed him, the Supreme Government resolved to retain the situation of Superintendent open until his return.

During Captain Everest's absence the establishment was usefully employed under the principal sub-assistant, Mr. Joseph Olliver, in extending a longitudinal series from the Seronj base line to connect Calcutta, for which work written instructions were given by Captain Everest. This series traverses, throughout the greater part of its extent, a wild, desolate, and unhealthy tract of hill country, which presented formidable difficulties. Notwithstanding the frequent ravages of jungle fever, which has all along been the most baneful enemy of the trigonometrical survey, as well as one of the chief retarding causes, this party, composed entirely of East Indians, successfully overcame all obstacles, and the work was eventually brought to a close in the year 1832, at the Calcutta base line, having occupied a period of six years in accomplishing a direct distance of 671 miles. The progress, therefore, was at the rate of 112 miles per annum, including branching series of secondary triangles. On account of the defective state of the instrumental equipments, the professional value of the work is only of a secondary or tertiary order. The area comprised in these operations is 33,442 square miles.

Colonel Everest returned to India in 1830, liberally provided by the munificence of the Hon'ble Court of Directors with geodetical instruments and apparatus of every description, in the construction of which the most skilful artists of the day, Messrs. Troughton and Simms, exhausted every resource of modern invention. The equipments consisted of a complete Base line apparatus, the invention of Colonel Colby, precisely similar to that employed on the Ordnance survey; a great Theodolite, 36 inches in diameter, designed by Troughton, which even at the present day is supposed to stand unrivalled by any other instrument of the kind in the whole world, and which most probably

will never be surpassed; two 18-inch Theodolites, and a variety of smaller instruments from 12 inches diameter downwards, all by the same celebrated maker. The signals, all of the most efficient kind, and recently invented, consisted of Heliotropes, reverberatory Lamps, and Drummond's Lights, of which the two former have been exclusively used; and here it may be remarked, that the substitution of luminous signals for opaque ones has contributed vastly to the improvement of the observations. These modern inventions together with the extreme precision of Troughton's graduation, as well as the high optical power employed, and the rigorous system of changing zero, introduced by Colonel Everest, has brought the terrestrial operations to a refinement of accuracy which may almost be pronounced unsurpassable.

During his absence from India, Colonel Everest had made himself acquainted with the English Ordnance Survey system, and with every modern improvement in geodetical matters that had taken place in Europe. The apparatus supplied by order of his Hon'ble masters was superior to any in the world, and London artist, Mr. Henry Barrow, was sent out to maintain the apparatus in order. Thus splendidly equipped, Colonel Everest returned to India in the prime of life, the full vigour of his faculties, and with an undaunted determination of character that never quailed before any difficulties, nor yielded to any opposition. The task before him required indeed the full display of all the vigour he possessed. In addition to the duties of Superintendent of the Trigonometrical Survey, he had now to perform those of Surveyor-general of India, to which office he had recently been appointed by the Hon'ble Court of Directors. This union of offices, though it served to facilitate arrangements, nevertheless vastly increased his labors at the outset; for the apparatus being new to India, and the establishment untrained, the whole task of teaching devolved on him unaided. In 1833, moreover, the offices of Deputy Surveyor-general at Madras and Bombay were abolished, which further increased the duties of the Surveyor-general of India, so that Colonel Everest had, in fact, to perform the work which had hitherto occupied the undivided attention of four officers. In the sequel these reductions have been found to operate conveniently enough, and so far have justified the expectations of the Hon'ble Court by whom they were

ordered, but the additional labor thrown on the Surveyor-general at the time that the Trigonometrical survey was about to recommence on a new organization, made his task a very arduous one.

He was detained by all these arrangements, by official delays, and by the measurement of the Calcutta Base line, until the end of 1832, from which time the Great Arc may be considered to have actually recommenced, after a cessation of seven years. The work was carried on unremittingly till December 1841, when the whole Indian arc, from Cape Comorin to the Himalaya mountains, forming the main axis of Indian geography, was finally completed.

These operations are fully detailed in Colonel Everest's book, published in 1847, by order of the Hon'ble East India Company. The area comprised by the Great Arc operations, principal and secondary, aggregates 56,997 square miles, including the revision of the section from Beder to Kalianpur, and the measurement of three base lines, each from 7½ to 8 miles in length, viz., those of Beder in lat, 18° : Seronj, near Kalianpur station in lat. 24° and the Dehra base about 70 miles N. of Kaliana station in lat. 29·30, where the Great Arc actually terminates, this distance being observed on account of the proximity of the Himalayas.

On comparing the actual measurement of the Dehra Doon base (by Colby's apparatus) with that calculated from the Seronj base measured in 1824 (by the chain), a difference of nearly 3½ feet was found. In former times this would have been considered a very satisfactory agreement, seeing that the length of the base is 7½ miles, and its distance from the new base upwards of 400 miles in a straight line; but Colonel Everest justly considered the difference as indicating a much larger error than ought to exist, regard being had to the precision of the new methods; and, in order to set the question at rest, he resolved to re-measure the old base with the more accurate apparatus he now had at his command. This operation was completed in January 1838, when it appeared that the length given by the chain measurement of 1824 was too short by nearly three feet, as compared with the new result.

The Plate represents the termination of the Measurement of the Calcutta Base in 1832, by Colby's apparatus. The six sets of bars are resting upon their tripods, levelled and in the act of adjustment, longi-

tudinally, by means of the directing or boning telescope, to the left hand. The boning telescope ought to have been considerably more distant from the bars, but it would then necessarily have been excluded from the drawing. A moveable covering of tent-frame work protects the bars from the influence of the morning sun; at their left extremity is seen a cast-iron tripod, firmly imbedded in the ground, bearing a brass vertical cylinder and plate, upon the surface of which is the minute dot which marks the termination of the last, and acts as the starting point of the present measurement, by the adjustment of the cross wires of the end microscope in the true vertical line bisecting the dot. These apparatus are represented on a larger scale in the foreground; as also one of the wooden boxes containing the compound bar, showing the two projecting tubes, within which lie the cross levers of the compound bars, upon which are engraved the dots, or marks to be read off by the double microscopes interposed between each box, as will be comprehended by reference to the drawing. The right extremity of the line is seen to enter the door of the tower, where it terminated in a coincidence with the original dot, engraved upon a metallic disc attached to a sunken stone pier.

The great accuracy and value of this apparatus may be judged of by the measurements of the three bases of the Great Arc. The Dehra Doon base is nearly $7\frac{1}{2}$ miles in length. The ground is undulating and by no means favorable; the line is twice intersected by the stream of the Asan; and the height above the sea level of one end of it is 186 feet greater than that of the other. The base was measured twice, first from west to east, and then in the opposite direction. After all reductions the two results were as follows:—Length in feet at the level of the sea—by the measurement, 39183·97329; by the remeasurement, 39183·77357; difference, 0·19972, corresponding to two inches and (nearly) four-tenths of an inch. Another test was applied with an equally satisfactory result. The entire line was divided into three sections, and the two end sections deduced from the middle one by triangulation. The discrepancies between the measured and computed distances were + 0·333 of an inch in the one case, and — 0·078 of an inch in the other; so that the whole base, deduced in terms of the middle section, differed from the length actually measured by scarcely more than a quarter of an inch.

The other two bases, at Seronj and Beder, were measured exactly in the same manner as that in the Dehra Doon. In the case of the Beder base (nearly 8 miles) the measurement was tested by dividing the whole length into three sections, and computing the two end sections from the middle one by a triangulation. The difference was found to amount only to an inch in the one case, and about two-thirds of an inch in the other; the computed length exceeding the measured length in both cases.

The superb Theodolite above mentioned had an azimuth circle of 34 inches in diameter, and by means of five miscroscopic micrometers the divisions could be read to one or two-tenths of a second. It carried a telescope of 39 4 inches focal length; the attached vertical circle was 18 inches in diameter; and every contrivance had been applied to provide for accuracy and facility of adjustment, which the genius of the artist could devise.

In order to eliminate instrumental errors and obtain results of uniform precision, the angles were measured from eight different zeros on the circle, the established rule being "to observe three times at each zero with the face left and as many with the face right, then to change the zero three times by 9° each time, and at each position go through a like operation, whereby it is evident that every ninth degree will in turn fall under one or other of the microscopes."

Great importance was attached to the construction of the Stations. Throughout the Doab it was necessary to erect artificial structures of sufficient height to overtop the trees, and of sufficient solidity to afford a firm support to the theodolite. These were of a very substantial kind—square towers of solid masonry, about fifty feet in height, with walls five feet in thickness at the foundation, and two at the top. A stone slab, supported on two transverse stone beams, formed the floor on which the instrument stood: and the stage for the observers was entirely disconnected in order to avoid vibration while the observations were going on. The centre of the station was carefully defined on a plate of metal let into a stone, and sunk in the ground for further security, and the theodolite and signals were in all cases accourately adjusted over the centre. The sites of stations were also carefully selected with a view to *well-conditioned* triangles. It was a general rule, steadily adhered to, that no angle of any triangle should be less

than 30°. The sides of the triangles may be stated to be from ten to twenty-five miles. In a very few instances only are they found so much as thirty miles.

The Heliotrope was used for day observations; it affords an exquisite object for bisection, but as it must be adjusted by signals from the observer, it was only available for short distances. Reverberatory Lamps, with argand burners, and enclosed in air-tight cases, were generally used by night; and when these were found to be too feeble, recourse was had to blue lights, burned at regulated intervals. Means were provided to prevent any rays from the luminous object reaching the observer at the telescope, excepting those which passed over the centre of the station. With the heliotrope and blue lights it was found to be scarcely possible to arrange for the observation of more than one signal at the same time; and hence the usual mode of proceeding was to take the angles between a mark of reference set up at some convenient distance from the station where the instrument was placed, and the signals displayed from each of the surrounding stations successively and independently.

For computing the sides of the Triangles, the theorem of Legendre was used. Of the sufficiency of the methods, and the great precision of the whole of the geodetical operations, the most satisfactory proof is found in the agreement, almost absolute, in the lengths of the two bases at the extremities of the arc, as found by actual measurement and by computation through the series of triangles from the one near the middle. The results are as follows:—the length of the Dehra Doon base, brought out by computation from the Seronj base, was found to be 39183·273 feet, and by the actual measurement, 39183·873 feet, the difference being 0·600, or six-tenths of a foot; that is to say, a little more than seven inches, the distance between the two bases being about 430 miles. Again, the Beder base brought out by computation from the Seronj base was found to be 41578·178 feet, and the length given by the measurement was 41578·536, the difference in this case being only 0·358 parts of a foot, or a little more than four inches, the distance between the two bases being about 426 miles, and the calculation made through 85 principal triangles. The agreement is certainly remarkable.

The relative Heights of the stations were determined by means of

observations of their vertical angles, as seen from each other, made with 18-inch altitude and azimuth circles. The observations were reciprocal, that is to say an observer was placed at each of two stations whose difference of altitude was to be found, with a heliotrope or lamp by the side of his instrument, and each observed the angle between the zenith and the signal of the other at the same instant of time, according to preconcerted signals. This method is perhaps the only one which can be depended on in any country, but especially in India, where the effects of terrestrial refraction are so great and irregular.

For deducing the amplitude of the northern section (Kalianpur, (Seronj) to Kaliana) thirty-six stars were selected, half of them to the south and the other half to the north of the zeniths of both stations, but none of them having a zenith distance exceeding 5° from the nearest vertical. The observations were not, as was intended, strictly simultaneous, Captain Waugh having commenced his observations at Kalianpur a few nights before the time agreed on, and Colonel Everest and Captain Renny, who observed at Kaliana, having met with some interruption from unfavorable weather. For the southern section thirty-two stars were observed at Kalianpur and Damargida (Beder), and in this case the observations, with scarcely an exception, were literally simultaneous. Precise rules were laid down with respect to the mode of observing, reading the microscopes and levels, changing the zero points, &c.; and every necessary precaution appears to have been taken to obtain results free from instrumental errors.

Further details will be given in a subsequent paper of the methods of observing and computing employed in the Indian Trigonometrical Survey.

In the year 1829, a trigonometrical survey in the Bombay Presidency was commenced by Lieut. Shortrede, on an independent base and point of departure. These desultory principles were objected to by General Hodgson, at that time Surveyor-general of India, who recommended that the work should emanate from the Great Arc, and proceed to Bombay precisely according to Colonel Lambton's original design. This injunction, however, remained unheeded; and notwithstanding the respect due to Colonel Lambton's judgment, and General Hodgson's authority, the survey proceeded in an unsystematic manner

until it was brought under Colonel Everest's control in 1831. Finding that no use could be made of this confused net of triangulation, the Colonel directed that the longitudinal series should be taken up where he left off in 1823, at the time of Colonel Lambton's death. Lieut. Shortrede resigned in 1836, and was succeeded by Lieut. Jacob, of the Bombay Engineers, by whom the Bombay longitudinal series was brought to a conclusion in the year 1841, and the whole work now rests on his observations alone. This officer united to considerable mathematical attainments, great practical skill as an observer and mechanic; and although the instrument employed, a 15-inch theodolite, by Dollond, was small for such extended operations, no man could have turned it to better account, and the work accordingly bears a superior character for accuracy. The series extends 315 miles in length, and having occupied 12 years, progressed at an apparent rate of only 26 miles per season; but in fact the only efficient part of the work, viz., that executed by Lieut. Jacob, was performed in three seasons.

Immediately after the measurement of the Calcutta base, Colonel Everest fitted out a party under Lieutenant James Western, of the Engineers, for the purpose of carrying a triangulation along the meridian of Parisnath, dependent on one of the sides of the Calcutta longitudinal series. This work commenced in February 1832, Lieutenant Western continuing in charge till September 1834, when he was relieved by Lieut. Bridgman, of the Artillery, who shortly afterwards was compelled to relinquish the duty from ill health, induced by exposure and fatigue, which obliged him to proceed to Europe on medical certificate, and soon after this promising young officer died on the voyage. No final work that could be made use of was executed up to this period, and the cost incurred, Rs. 35,224 was in fact fruitless. Lieut. (now Lieut.-Col.) A. H. E. Boileau assumed charge in 1835-36, and commenced the work *de novo*. Excepting an absence of six months on medical certificate, he continued to conduct the triangulation till December 1838, when he resigned his appointment in the Great Trigonometrical Survey for one of superior emolument and less exposure; the small portion remaining to connect the series with Lieut. Buxton's triangulation in Cuttack, was executed by Mr. Sub-assistant Kallonas. On account of defective instrumental power, this work is only of a second-rate order.

Colonel Everest at the end of 1832 fitted out another party, under Lieutenant Roderick Macdonald, of the Bengal Native Infantry, to carry on the Budhun meridional series, dependent on a side of the Calcutta longitudinal series. Lieutenant Macdonald broke ground on the 2nd February 1833, and was obliged to relinquish the work in September 1835, on account of ill health produced by exposure. Consequent on the departure of Lieutenant Macdonald, Lieutenant Ommanney, of Engineers, was placed in charge, and he remained in that post till April 1837, when he resigned his appointment, and was succeeded by Mr. Olliver. In the early part of 1838 operations were suspended on account of Mr. Olliver's services being required with Lieutenant Waugh on the Great Arc. Up to this time the progress of the Budhun series had been satisfactory as far as the hilly country extended, and ceased to be so as soon as the operations entered the flat lands in the valley of the Ganges. Until November 1839, no officer or sub-assistant of experience being available, the work remained suspended, but on the conclusion of the Amua series, the party under command of Lieutenant Renny (now Captain Renny Tailyour) was transferred to this series, and placed under Mr. Sub-assistant Murphy. After the termination of the Great Arc, on which Captain Tailyour had been employed, he proceeded to take personal charge of the Budhun series, and the work was at length brought to a successful conclusion by that able and energetic officer in one season, having occupied in all no less than eleven years from the commencement. The reasons for this slow progress may be inferred from this narrative. The area covered amounts to 12,468 square miles.

In 1832, Captains Waugh and Renny (Tailyour) joined the Survey Department, and were employed in exploring the wild and jungly country between Chunar and the sources of the Soane and Nerbudda rivers, and up to the city of Jubbulpore. This extensive survey was completed in the season 1832 and 1833, and formed the subject of a topographical and geological report, submitted in 1834. After closing the work at Jubbulpore in March 1833, they proceeded to join the approximate operations of the Great Arc series in the Gwalior country, with which they remained till August of the same year, when they were ordered to organize two parties, one for the Ranghir meridional series under Captain Waugh, the other for the Amua meridional series under

Captain Tailyour, both series being dependent on sides of the Calcutta longitudinal series. In December 1834, Captain Waugh joined the Great Arc as astronomical assistant, in which capacity he remained until he was selected to succeed Colonel Everest, on that officer's retirement from the service in December 1843.

The Ranghir series was completed in 1841, having occupied nine years. The meridional distance comprised is about 400 miles, showing an average progress of 44 miles per annum. The area covered amounts to 16,088 square miles.

The Amua series was brought to conclusion by Captain Tailyour, in June 1839. The instrument used was a good 18-inch theodolite, by Troughton and Simms, and the work possesses superior merit. The area comprised is 5,565 square miles.

Lieutenant W. Jones, of Engineers, was appointed to the trigonometrical survey in the year 1835, and remained till 1838 attached to the Great Arc. After the measurement of the base near Seronj, in which operation he took a part, Lieutenant Jones was deputed to conduct a series on the meridian of Karara, dependent on a side of the Calcutta longitudinal series. The work was commenced, but towards the close of 1838 the whole party was attacked by jungle fever, from the effects of which one sub-assistant, Mr. Scully, died, and Lieutenant Jones himself was obliged to seek for restoration to health in the hills. In consequence of this disaster, a fatal stop was put to the progress of the work. The establishment was broken up, and the work remained in abeyance till 1845, when it was completed by Mr. Armstrong, who had previously been employed in the Ranghir series. The instruments employed were of an inferior order, and this series cannot, therefore, be considered a first-class performance. It embraces an area of 5,819 square miles.

(To be continued).

BRICKWORK IN INDIA.

OVER the plains of Hindoostan and the Punjab for many years to come, must Brick be the chief material used by the Architect and Engineer for his building constructions; the cost of carriage and working, putting stone out of the question in any but very exceptional cases. The improvement of his Brick-work in material and workmanship ought therefore to be a subject worthy of his best consideration, on the part of every Engineer and Overseer in the above localities. I have already remarked in a former article (Vol. I. p. 201) on the unsatisfactory state of the building art in India, as exemplified in the tasteless plastered buildings which everywhere abound, and wish again to urge attention to this subject, because I think that with some care and skill, a great improvement in this direction may be carried out at small expense. The neglect of it has arisen a great deal from the little attention that has been bestowed on Brick Architecture in England,—where, when stone is not much used (as in London for example), stuccoed buildings everywhere abound. Old red brick houses of the age of Anne are not uncommon in country towns, and perhaps the excessive ugliness of their architecture has helped to bring the material into discredit; it is only quite recently that architects have turned their attention this way, and have showed how by care in the manufacture, and tasteful arrangement in the colors of their Bricks, it is possible to produce very pleasing architectural effects with an economical yet durable material, and which resists, far better than Stucco, the changes of a variable and trying climate.

It is rather to the Continent than to England that we must go for fine examples of chateaux and other structures in Brick which there abound, and it is from a German work * lately published and probably little known to my readers, that the annexed designs are taken. I have selected them, not because they are the best in the work, but because they are simple, and might I think be imitated by any Engineer who will take the necessary trouble.

Good clay for Brick-making is tolerably plentiful in India, and three or four varieties may be found in most districts. The bricks commonly used are well burnt, but owing to the little care bestowed on the choice or mixture of the earth, to the non-use of the pug-mill, and to carelessness in moulding, stacking, and burning, Indian bricks as a rule are badly shaped, their texture not homogeneous, and their color *dirty* and not uniform. All this it is evident may be remedied by proper care and supervision; and by reserving the inferior bricks for the unexposed parts of walls and paying a somewhat higher price for the best to use as face-bricks, a great improvement would be cheaply effected. But I am not aware that any attention has been given to the subject of *colored* bricks, to be used for cornices, pannels and mouldings, and there is a very good field here for any Engineer who will devote himself to this detail of his profession. The colors ordinarily employed in England are deep red; yellow or salmon color (such as the London malms); blue (as in the Staffordshire blues); and white (as the Suffolk whites). All these colors are produced by a careful choice or mixture † of earths and not by any expensive chemical substances mixed with the common earths. The red is due to the presence of the peroxide of iron—the blue color is produced simply by the application of greater heat to various earths which ordinarily burn red—white bricks are made from a plastic white clay—the London malms by mixing chalk and clay in a liquid state.

I think careful enquiry will show that one or more of these

* Vorwort, by Ludwig Degen, Ingenieur. Munchen.

† In Staffordshire there are seven marls used, differing little in their chemical composition, and when used three sorts at least are generally mixed together (see Weale's Treatise).

colored bricks could be produced in most districts, and, if only used in the ornamental parts of a building, it would be often worth while to import them from a considerable distance, if they were not procurable on the spot. There are surely some practical men in the profession in India who will turn their attention to so useful a subject, and give others the benefit of their experiments and experience; I shall be very happy to publish them *pro bono publico*. Any of my readers about visiting England I would strongly recommend to turn their attention to the practical solution of this question. I may add that I have sent home for specimens of colored bricks and of the raw material from which each sort is made, which will be deposited here, and may be useful as a guide in comparing Indian earths. Some experiments are also being made at Roorkee, and I have succeeded partially in making black bricks, but have not as yet been able to burn them white or yellow; should any of these trials be of sufficient interest to others they shall be duly recorded.

J. G. M.

No. LXXXII.

THE ALGUADA LIGHT-HOUSE.

Constructed by Lieut.-Colonel Alex. Fraser, R.E.

At the close of the year 1853, the attention of the Marquis of Dalhousie, then Governor General of India, while on a visit to the newly acquired Province of British Burmah, was drawn to the perils of the Alguada Reef, a dangerous line of rocks to the southward of Cape Negrais, and lying on the direct course of vessels sailing from Calcutta to the Irrawaddy and to the great security that would be afforded to navigators by the construction of a Light-house there.

After some correspondence, the Court of Directors of the E. I. Company in 1856, desired that an Engineer Officer should be deputed to make the necessary surveys and submit a complete report and estimate of the proposed work; and Captain Alex. Fraser, R.E., was appointed to the duty. He was desired, after making a careful survey of the site, and taking into consideration all the circumstances that would affect the actual construction, to submit a preliminary report, and then to proceed to England for consultation with Mr. Allan Stevenson and other eminent Light House Engineers, after which his detailed designs were to be prepared. In February 1857, the first report was accordingly submitted, from which the following description of the Reef is taken.

"The Alguada Reef, consists of two totally distinct ridges of rock, running parallel to each other, separated by a channel a quarter of a mile wide, of a depth varying from 2 to 3½ fathoms, with a small detached rock in the centre appearing above the surface at low water. The rock of which the entire reef consists is sandstone. The rise and fall of spring tides I found to be 9 feet.

"After carefully examining every part of the Reef which was at all accessible, I

finally fixed upon a plateau on the eastern ridge, 600 feet distant from the S. W. extremity, as the site most suitable for the erection of the Light-house.

"The reef at this place is a firm solid mass of rock, presenting a nearly level surface of 100 feet in width, with an average height of 1·1 feet above high water spring tides."

After giving his reasons for preferring Stone to Iron as the material to be employed, Captain Fraser pointed out the island of Callagouk, distant 210 miles from the reef, as the source of supply which he would propose. Captain Fraser then proceeded to England, and in the following November submitted his detailed report and designs to the Hon'ble the Court of Directors, who expressed "their full satisfaction with the manner in which he had fulfilled the commission entrusted to him by the Government of India," and on that design the work was accordingly executed. The following is extracted from this report :—

"Of all the Light-houses that I know or have visited, the Skerryvore, designed and erected by Mr. Alan Stevenson, on the Western coast of Scotland, is in the position most analogous to that of the Alguada Reef.

"Every Engineer is, of course, desirous of submitting original designs, but so perfect in every way does this structure appear to me to be, not only in design, but in workmanship, and not only in beauty of appearance, but in accuracy of calculation with reference to stability, that I feel quite sure I can do no wrong in taking it as my model, with, of course, certain interior alterations necessary to the different interior arrangements that will be required to suit it for the dwelling-place of people of different races, and in a different climate . and if I can, with the unskilled labor I shall be able to obtain, execute the work on the Alguada Reef in the same successful manner as that has been executed on the Skerryvore, I feel that, though I may have shown no originality of design, I shall be entitled to no small credit in the construction.

"The diameter of this Tower is 42 feet, the height of the shaft is 120 feet, and the diameter at this height is 16 feet Above the shaft is a cylindric belt, 18 inches deep, surmounted by a cavetto 6 feet high, with a 3 feet projection. The cavetto supports an abacus 3 feet deep, the upper surface of which forms the balcony. On the abacus rests the parapet, and on it the lantern. The outer surface of the shaft is formed by the revolution of an hyperbola round its asymptote as a vertical axis—the radius at the base being 21 feet, and at the top 8 feet. The contour of the cavetto is obtained from the quadrant of ellipse revolving about the centre of the Tower with a radius of 8 feet on the level of its transverse axis.

"In adopting this curve for his Light-house, Mr. Alan Stevenson observes, in reference to the stability of buildings exposed to the force of the sea, that the sum of our knowledge appears to be contained in the following proposition :—'That, as the ultimate stability of a sea-tower, viewed as a monolithic mass, depends, *cæteris paribus*, on the lowness of its centre of gravity, the general notion of its form is that of a cone ; but that, as the forces to which its several horizontal sections are opposed decrease towards its top in a rapid ratio, the solid should be generated by

the revolution of some curved line convex to the axis of the Tower, and gradually approaching to parallelism with it' " He then goes on to show that he tried several forms, and proves a clear superiority of the hyperbolic curve over all others, as far as the advantageous arrangement of the materials is concerned.

"I therefore think the Hon'ble Court can do no better than authorise Mr. A. Stevenson's design for the Light-house on the Skerryvore, as the model of form on which to build the one proposed for the Alguada Reef.

"The focus of the light will be 142·5 (= height of tower) + 1·1 (= height of site above spring tides) = 113·6 feet above high water spring tides, which height will permit the light to be seen, supposing the eye of the observer on the horizon, and taking into consideration the effect of atmospheric refraction at a distance of 15·85 miles. If we take the height of the observer's eye to be 20 feet above the horizon, then the light will be visible at a distance of 21·766 miles, and at 50 feet above that level, 25·204 miles."

Financial difficulties, consequent on the mutiny, prevented the immediate commencement of the work, but during the N. E. monsoon of 1859-60, work was really begun, and consisted in cutting out the foundation to a depth at the lowest part of $7\frac{1}{2}$ feet below high water spring tides, about 700 tons of rock being removed. The work was done by common "classies" picked up in Calcutta, assisted by the crew of the steamer "Nemesis," and the chief trouble was to keep the water out of the foundation, which with the least sea was constantly being filled. In the mean time an establishment had been organized at the island of Callagouk, whence the granite was to be quarried and conveyed to the reef in lighters, towed by the steamer; and no little difficulty was encountered in starting such an establishment in a dense jungle on an uninhabited island. Laborers were procured from Madras and Hong Kong, and set to work under Lieut. J. McNeile, R.E., but so great were the difficulties that eventually it was found necessary to prepare part of the stone at Singapore. It was not until the 14th February 1861, that the first granite stone was actually laid, and 104 stones, weighing 74 tons, were laid before the setting in of the monsoon caused the stoppage of work for the season. The weather during this and the following season was most unfavorable and caused great delay and anxiety.

By the end of the third season, however, the seven lower courses of stones were duly laid, each stone varying in weight from half a ton to $3\frac{1}{2}$ tons. They were all lifted into position by the crane by means of *lewises* previously cut—the outside stones being laid in Portland cement, the inner in lime and soorkhee.

During the fourth season (1862-63) the work was completed up to the

18th course, or above the lower room, being rather more than half the whole quantity, and by the end of the fifth season (1863-64) the whole stone-work was complete with the exception of the parapet, and the four top courses of the capital, 1,600 tons of stone having been raised that year.

On 23rd April 1865, the light was for the first time shown, and the Governor General in Council offered "to Lieut.-Colonel Fraser the cordial thanks and congratulations of the Governor of India on the successful issue of his labors."

"Lieut.-Colonel Fraser," says the Government order, "applied himself to the task with a zeal and judgment which have ensured success."

"To land on the Reef is always a difficulty. For a vessel to be thrown on it at any time is almost certain destruction, and in any but the calmest weather the seas break over it A first care, therefore, was the formation of a suitable marine establishment for the transport and landing of materials, for the safe conduct of operations, and for a secure refuge in stress of weather Skilled workmen had to be brought from Madras, and even from Hong Kong Materials, provisions, and water, had also to be arranged for

"The foundation had to be cut in the solid rock to a depth of 7½ feet below high water spring tides, with the sea breaking over and filling the pit at high water, and very little wind preventing all work.

"For the lower foundation courses, sandstone was quarried and dressed on the Reef. For the tower, granite had to be obtained from Callagouk, 200 miles, and Singapore, 1,200 miles, distant. Upwards of 4,000 tons of granite in heavy blocks, some weighing nearly four tons, requiring accurate dressing, had to be shipped and conveyed to the Reef, and there placed in position, the landing involving an almost daily contest with the elements. This was accomplished in four seasons, of which three proved very unfavorable, with the loss of no life, but only of a few boats, of one lighter with 40 tons of stone, and with injuries to only a few of the workmen

"The forethought, resource, energy, and perseverance displayed, and the anxiety, risk, exposure, and hardships endured, entitle Lieutenant-Colonel Fraser, and all under his orders, to the highest commendation.

"It is seldom that it falls to the lot of any individual, in India especially, to carry through from beginning to end a work of such magnitude and extending over so long a period The work itself is unique, certainly in the East, and, whether regard be had to cost, execution, or rate of progress, may challenge comparison with its somewhat smaller prototype, the Skerryvore on the coast of Scotland"

The Engraving on the Frontispiece is from a Photograph taken on the spot, and sent to the Editor by Col. Fraser. It is understood that a complete history of this important work will shortly be published by Government.

The total cost of the work was about 10 lakhs of Rupees (£100,000).

J. G. M.

No. LXXXIII.

INDUS SILT EXPERIMENTS.

(2ND ARTICLE.)

Description of the mode adopted in taking the Observations recorded below, to determine the Velocity of, and the amount of Solid Matter in, Water, at different depths in the Indus. BY COLONEL TREMENHEERE, R.E., *Chief Engineer in Sind.*

As it was desirable to ascertain the amount of silt in the Indus water during the winter season when the river is low, the observations were continued at Kotree in the month of November 1864, from a boat anchored at several points in nearly a direct line between two stations on the opposite banks of the river. I hoped thus to obtain a correct section of the river with observations of the velocities, and to be able to calculate with some accuracy the total discharge. I was, however, foiled by the great depth of water, and the strength of the current in the centre of the section. On the 25th November, with a depth of 14 feet, and a surface velocity of 4·7 feet per second, I found that the wooden pole to which the instrument was fixed was unmanageable, its buoyancy rendering it almost impossible to force it to the bottom by the time it came into a vertical position, or to retain it in that position. In one portion the depth was as much as 18 feet, and I could neither observe the velocities, nor take specimens of water at so great a depth. Although the observations then taken are not so complete as I had hoped to obtain, they are still valuable.

The only difference in the mode of observation from that previously described, was in the adoption of a bottle of a new pattern for taking water from the different depths.

A drawing of the apparatus is given. The cylindrical vessel slides upon

a piece of iron gas pipe graduated to feet and inches. This arrangement is much less acted upon by the current; it is immaterial in what position it is held, and one string suffices to work the valves.

The adoption of the gas pipe for this instrument, led to its employment also for the stream measurer, instead of the wooden rod, which was found unsuitable for any considerable depths, and both instruments now work on the same rod. I was able to dispense with the groove in the rod as a guide, by having a cross head to screw on to the top of the pipe, and by taking care to arrange the axis of the stream measurer as nearly as possible in the same vertical plane as the cross head.

In all other respects the observations were taken in precisely the same manner as those previously described, and the filtering observations were conducted with the same care.

Although I failed to obtain a complete section of the river at Kotree, with corresponding observations for velocity and silt, I was more fortunate at Sukkur, where, with the same apparatus, observations were taken at eight points at intervals in a direct line across the river.

The section of the river plotted to scale is given, but as the surface level of the river varied considerably during the nine days occupied by the observations; in calculating the discharge, I have reduced the depths and mean velocities to correspond with the state of the river on the 24th December, which gives the total discharge 68,114 cubic feet per second.

The position of the section is some way above the pass of the river between Sukkur and Roree at right angles to the bank, and about 200 feet north of the building marked Karkhana on, Plate VI.

The whole of the observations are given without any attempt to reconcile apparently anomalous results. With the single exception of those taken on November 25th, the experiments were made by myself and my Assistant, Captain Cotgrave; for that day alone a clerk belonging to my office gave me his help.* For the correctness with which the filtering, drying, and weighing, have been performed, I alone am responsible. It seems unnecessary to describe these processes in detail, as they must be familiar to every one who has been instructed in chemical manipulation, and as the details are described in books on that subject.

An examination of the recorded velocities at different depths, will, I

* I take this opportunity to express my obligations to Mr. F. Jones, C.E., Acting Executive Engineer, Upper Sind, for the assistance he rendered to me throughout the observations taken in the months of July and August last.

think, show that some confidence may be felt in the correctness of observations with the instrument employed.

With respect to the variation in the proportion of silt at different depths, I would remark that the results are given precisely as they were obtained, without offering any explanation of the fact, that there was more silt in water taken on the 23rd November at 9 feet from the surface, than in water taken within a couple of minutes at the same spot, from a depth of 11 feet,—and more in water taken on the 24th November from a depth of 8 feet, than from a depth of 12 feet. The facts prove that the material in suspension is not distributed in any exact proportion to the depths and velocities. Taken as a whole, however, the results show but few of these anomalies. In the Sukkur observations, the proportion of silt increases with the depth with considerable regularity, though here also a few exceptions occur.

The mean result of the observations at Kotree in November, is that the quantity of silt amounts to the 1-672 part of the water by weight; but as no observations were taken where the river was deepest and most rapid, this fraction is too small to represent the proportion in the whole discharge of the river.

The observations taken at Sukkur give the proportion 1-516, but this again, owing to the access of flood water during the experiments, gives too large a value, and I am disposed to adopt as an approximation 1-550 or 1-600, say 16·6 parts in ten thousand as the proportion of silt by weight in the whole discharge of the river during the low season, or as nearly as possible half that contained in it during the height of the inundation, viz., 33·3 parts in ten thousand.

I have failed hitherto to find any part of the river where the banks on each side are well defined during both the high and low seasons, and where the depth in the latter period is such, that observations can be taken throughout the section. If the correct measure of the discharge at such a section during the low season could be obtained, a close approximation could be made to that of any period of the inundation, by merely taking the velocities at the surface.

The section at Sukkur herein given, being bounded on the left bank by low land which is submerged in the high season, cannot be used for the above purpose. The maximum discharge of the river at Sukkur may however be considered as 3,80,000 cubic feet per second.

RECORD OF OBSERVATIONS TO ASCERTAIN THE AMOUNT OF SILT CONTAINED IN THE WATER OF THE INDUS IN THE MONTHS OF NOVEMBER AND DECEMBER 1864.

Date.	Site.	Gauge.	Depth of Water.	Depth from Surface.	Velocity per Second.	Quantity of Water.	Deposit on Filter	Proportion of Silt to Water.	Remarks
		ft. in.	ft. in.	ft. in.	feet.	lbs. oz. drs	grains		
1864. Nov. 23,	Kotree,	3 2	13 0	11 0	1·68	3 1 5	27	1-804	
				9 0	2·166	3 0 4	29	1-734	
				7 0	2·37	3 0 1½	26	1-810	
				5 0	2·62				
				4 0		3 1 6	32	1-895	
				3 0	2·68				
				1 0	2·73				
						12 4 0½	114	1-768=·00130	
Nov. 24,	"	3 0½	14 0	12 0	1·85	3 0 3	25	1-846	
				8 0	2·52	3 0 5	46	1-462	
				4 0	3·06	3 1 7½	34	1-642	
				Surface	3·48	3 2 3	28	1-787	
						12 5 2½	133	1-654=·00153	
Nov. 25,	"	3 0	14 0	12 0		2 13 2	37	1-535	
				8 0		3 1 0	30	1-714	
				4 0		3 3 1½	33	1-678	
				Surface	4·7	2 1 6	20	1-738	
						11 3 1½	120	1-653=·00153	

Date.	Site.	Gauge.	Depth of Water.	Depth from Surface.	Velocity per Second.	Quantity of Water.	Deposit on Filter.	Proportion of Silt to Water.	Remarks.
		ft. in.	ft. in.	ft. in.	feet.	lbs., oz. drs	grains		
1864. Nov. 26,	Kotree,	2 11	16 0	14 0	1·38	3 0 0	24	1-875	
				10 0	1·85	3 1 5	27	1-804	
				6 0	2·22	3 1 4½	28	1-774	
				2 0	2·22	2 15 0	25	1-822	
				Surface	2·36				
						12 2 1½	104	1-817= ·00122	
Nov. 28,	"	2 10½	15 0	13 0	Variable owing to the existence of a backwater	2 15 0	45	1-457	
				9 0		3 0 4⅓	40	1-530	
				5 0		3 1 4¼	44	1-492	
				2 0		2 15 4	24	1-866	
						12 0 4½	133	1-550= ·00181	
				Total at Kotree,		59 15 2½	624	1-672= ·00149	
Dec. 24,	Sukkur,	0 7	7 6	5 6	1·75	2 14 3½	38	1-534	
				3 6	1·95	2 13 1½	20	1-988	
				1 6	2·66	2 15 0	20	1-1028	
						8 10 5	78	1-777= ·00129	
Dec. 26,	"	1 1	7 3	5 3	4·27	2 11 4¾	22	1-821	
				3 3	4·57	2 3 0	20	1-765	
				1 3	5·03	2 15 2½	23	1-809	
				Surface	5·03	2 3 2½	16	1-965	
						10 1 1¾	81	1-870= ·00115	

Dec. 27,	Sukkur,	1 8	9 8	7 8	4 86	2 2 5	38	1-398
				5 8	5 5	2 3 2	36	1-428
				3 8	6 26	2 6 0	33	1-503
				1 8	6·47	2 3 0	35	1-437
						8 14 7	142	1-440= 00227
Dec. 28,	„	2 0	9 0	7 0	5 16	2 5 6	90	1-183
				5 0	5 5	2 5 6½	60	1-275
				3 0	6·72	2 6 0	45	1-369
				1 0	6·93	2 6 0	44	1-378
						9 7 4½	239	1-277=·00361
Dec. 29,	„	1 11	7 4	5 4	5·54	2 3 4¾	36	1-432
				3 4	6·21	2 5 7	36	1-460
				1 4	6·80			
				0 4	6·80	3 3 3	39	1-576
						7 12 6¾	111	1-492= 00203
Dec. 30,	„	1 7	8 5	6 5	4·07	2 6 0	35	1-475
				4 5	4·74	2 6 0	33	1-503
				2 5	4·87	2 5 6	30½	1-541
				0 5	5 12	2 3 3	21	1-737
						9 5 1	119½	1-546=·00165
Dec. 31,	„	1 4	7 3	5 3	4·03	2 0 0	26	1-537
				3 3	4·62	1 5 2	28	1-332
				1 3	5 16	1 8 6	17	1-637
				0 3	5 29	2 2 0	20	1-743
						7 0 0	91	1-538= 00186

Date.	Site.	Gauge.	Depth of Water.	Depth from Surface.	Velocity per Second.	Quantity of Water	Deposit on Filter	Proportion of Silt to Water.	Remarks
		ft. in.	ft. in.	ft. in.	feet.	lbs. oz. drs.	grains.		
1865. Jan. 2,	Sukkur,	0 10	2 6	0 6	2·66	2 2 6	20	1-760	
			2 11	0 11	1·04	3 0 0	29	1-724	
				Surface	4 19	2 3 5	21	1-742	
						7 6 3	70	1-739=·00135	
				Total for Sukkur, -		68 10 5	931½	1-516= 00194	

C. W. Tremenheere, Col., R.E.

No. LXXXIV.

GHAUT TRACING IN NORTH CANARA.

By an Officer of the Madras Engineers.

Prior to 1862, the beautiful district of North Canara, formed an integral portion of the Presidency of Madras. Its seaboard extends from the 13° 30′ to the 15° parallel of latitude, and is indented with numerous river estuaries, that to the eye at least seem each of them destined by nature to be improved into splendid harbours. Towards the south, the line of Ghauts approaches within about five miles of the sea, but recedes very considerably towards the north; throwing out however long and craggy spurs, which impart a peculiar, and quite characteristic, picturesqueness to the landscape. The Ghauts, and for the most part their spurs, are clad in the richest tropical vegetation, ever green; so that from each peak, or commanding point, there is spread out before the beholder, a prospect, perhaps not surpassed out of the Brazils.

North Canara is bounded on the east by the open champaign of Dharwar, now famous for its cotton, and by the Nuggur division of Mysore; and on the north, by the Portuguese territory of Goa, and the wild Sawunt Warree country in the collectorate of Belgaum.

It was added to Madras in a most unimproved state, with its lines of communication undeveloped; and remained for many years uncared for in this respect. Beyond the few European officials engaged in the collection of the revenue; a small detachment of natives troops at Honore, a seaport and principal station, and an occasional visit from sportsmen; no representative of the government was personally acquainted with the

vast capabilities and interesting features of this truly romantic Indian Eden. Seaward, the chain of frowning Ghauts, having bamboo thickets at their bases; a rank undergrowth of jungle well stocked with leeches, precluding escape most of the way up; and a stretch of eighty miles of broken ground, densely wooded, to make way through on reaching the top; effectually hindered much intercourse between Dharwar and the coast.

From the east the same obstacles in inverse order, had to be encountered; while from both north and south, the sand of the sea shores is the only track by which to enter; there being to this day no made road betwixt Cannanore and Bombay. But difficulties so great, though they might deter an ordinary traveller, are made light of when they stand in the way of the requirements of trade; and at length the attention of the district officials was roused by the spectacle of droves of laden cattle passing to and fro in thick streams, and literally forcing a passage, through lonely, inhospitable forests, and along stony water channels, that take an almost headlong course down the flanks of the Ghauts. The aid of the Engineer was called in.

Before describing the different ports of North Canara, it is necessary to note that, from the beginning of June to the end of August, the monsoon rains deluge the district. On the coast some 100 inches and upwards of rain-fall are generally registered; at the crest of the Ghauts the amount is fully half as much again; gradually dwindling down, and becoming considerably less, or about 40 inches, on the Dharwar frontier, which is a hundred miles from the sea. This rainy belt is popularly known as the Mulnaad, or tract on which the south-west monsoon expends its violence, and Canara falls entirely within it Unlike the districts north and south of it, the chief part of the North Canara Mulnaad lies above the Ghauts, or on an average at a height of 1,800 feet above the sea level; so that there is a more equable and plentiful distribution of rain over the higher ground than is found on the corresponding plateau of Mysore, which is fringed by scarps 3,000 feet high, diaphragms, that turn much of it back through the lowlands, to the ocean whence it came.

This abundance of rain gives North Canara above the Ghauts, a luxuriance of vegetation, and an impenetrability, nowhere else along the western coast to be met with on so grand a scale, or uniformly spread over so wide an area. It conspires, with the cool sea breeze, the clouds, the foliage, and the elevation, to reduce the temperature so low, that, it is

not uncommon to observe the thermometer standing at 65° at 10 A. M., while in the hottest weather it is never above 80° in the shade at mid-day. Add to these amenities, the hilly nature of the district; the torrents; the deep dells, and the tortuous ravines; the forests of lofty trees; the cascades, which thunder down from the edge of the table land to the cultivated strip below that skirts the sea; and tracing Ghauts in Canara may be fitly termed the poetry of road-making.

The chief ports are, Coompta, Tuddri, Honore, and Sedashaghur, now called Karwar in Bombay official reports. Coompta is a small town situated upon a tidal river of no great size, and was, until the transfer of the district, the place to which cotton was conveyed in large quantities to be shipped. The best "Coomptas" were as regularly quoted in the newspaper commercial lists as their rivals, fair "Dholleras," unless indeed the bales stood upon their own merits as "Dharwar saw-ginned."

It has no capabilities as a harbour, the river being narrow, and its bar shallow. The craft to convey the cotton to Bombay, where it was screwed, lay in an open roadstead, and were loaded by means of cargo boats, which could alone come along side the merchants' wharves up the river. During the continuance of the monsoon no business was transacted. Coompta doubtless gained its importance from being the nearest point on the coast to Dharwar, which could be easily reached; as it had of a certainty nothing else to commend it. Until the year 1848, the trade was conducted in the face of enormous disabilities, as there was no made road leading to Coompta, and without them the Canara district is almost impassable. Relief was afforded by the opening of the Devamunny Ghaut, and the construction of a first-class metalled road from the head of the Ghaut to the frontier, *viâ* Sircy, a lovely spot, which became the head quarter station of the district, and the basis of subsequent engineering operations. The road was prolonged westward to Coompta, the only obstruction being a wide ferry half way, which is still crossed by boats. The Ghaut is on the easy gradient of 1 in 20, and rises along the hill-side through the thickest forest, and rankest undergrowth imaginable, for nine miles without a single zig-zag. The foot of the Ghaut is fifteen miles from Coompta and 40 miles from Sircy, and the height surmounted is 1,800 feet. Any kind of wheeled carriage can traverse it with perfect ease and safety, and the line is bridged throughout.

About this time, the Indian Navy Officers were making a survey of the

Canara coast, and brought the port of Tuddri into favorable notice. It is a small bay, in the shape of a horseshoe, with the mouth pointing directly out to sea. There is deep water on the bar, and vessels are able to enter and load inside the harbour, but the monsoon squalls unfortunately strike right in, rendering it useless as a place of refuge at that season, or indeed at any time during the prevalence of a high wind. With all this, Tuddri had its share of popularity; and a Ghaut, the Arbyle Ghaut, was made for the express purpose of leading the traffic to it. The Arbyle Ghaut is situated a good way north of the Devamunny Ghaut, and is about eighty miles from Tuddri. The length of the ascent is six miles, and the gradient is a little steeper than the Devamunny, or from 1 in 18 to 1 in 16. It is also a very bold work, carried through heavy jungle, and most ingeniously led across a narrow neck connecting the main mass of hills with the spur up which the road winds, by which most unsightly zig-zags are avoided.

From Iddigungee, at the top of the Arbyle Ghaut, there is an excellent road, 25 feet wide, and bridged, to the Dharwar frontier; most of which must have been nearly as difficult to trace as the Ghaut itself, owing to the pronounced features of the ground, and its being covered with trees and shrubs. For the greater part of its length this road is formed, as are indeed most of the Canara roads, in laterite soil, which is one of the best gravels in use for surface metalling. It is not easily cut into ruts, and presents a dry hard face a quarter of an hour after the heaviest rain. In fact, so much assistance has nature lent, by clothing the surrounding country with an even coat of grass of the richest green, by grouping the trees and bushes into pleasing clumps, that a person riding along the smooth red tinted highway imagines he has entered the well kept park of a nobleman, and half expects to get a glimpse of the mansion house at every turn.

About half way between the foot of the Ghaut and the sea, the Arbyle road, as it is called, separates into two branches; one conducting to Tuddri; and the other pursuing a direct course to the trifling sea side village of Ancola whence it turns north to Sedashaghur. When the transfer to Bombay was made, the road from Ancola to Sedashaghur was under construction, but is now reported to have been completed; the distance is about 20 miles.

Tuddri soon lost the reputation it had rather hastily acquired, as the

prospect of the harbour of Sedashaghur being rendered accessible to cart traffic drew closer; and the consequences of the American Civil War still further conduced to turn all eyes to the natural advantages of the superior port. Sometime prior to the transfer, an effort was made to find a shorter route from Iddigungee to Sedashaghur, than that *viâ* the Arbyle road and Ancola, and after some deliberation, a line was selected, that of course involved the construction of a new Ghaut. The work of tracing was commenced from Iddigungee, and the track lay along most rugged and peculiar features. For three or four miles the road is taken along the top of an elevated and narrow ridge, formed by the junction of deep valleys running transversely to it in opposite directions. At twenty miles from Iddigungee, the head of the Keiga Ghaut, as it is termed, is reached; the intervening country presenting magnificent views, where it is possible to see over the tangled foliage which lines the way. The trace of the new road and Ghaut to within seventeen or eighteen miles of Sedashaghur had been opened out by the close of 1861. The Keiga Ghaut is nine miles long, a good part of it is on a very gentle incline, and none of the gradients are in excess of 1 in 20, which experience has shown is the best suited to Ghaut roads on the western coast. When the bridges are built it will have no zig-zags. Thus many of them will be imposing structures, as there are rapid and formidable torrents to be crossed. Like the others, the Keiga Ghaut is richly wooded, and there is an immense amount of blasting in gneissose granite to be done in widening out the traces.

At seven miles from the foot of the Ghaut, which is situated in an almost unrelieved solitude, the road begins to run parallel with a tidal river, broad and deep, that disembogues itself at Sedashaghur. This river, or the Kalanuddy (black river), is navigable for steamers for at least nine miles inland at all times, but in the rains swells out to an impetuous and noble stream. In the dry weather, timber rafts are floated down it from the teak forest of Goond, which lies in the direction of Sawunt Warree; and the sale of the logs forms no inconsiderable part of the revenue which the district yields to Government. The harbour of Sedashaghur would take too long to describe; and it must suffice to mention that it is sheltered by a projecting head land from the gales of the monsoon, and affords a spacious anchorage for every class of vessel.

Honore is far to the south, and comparatively of no great value or

importance. On an estuary of a river bearing the same name, with a shallow and exposed bar, the traffic in spices and salt is entirely local; but even that is accommodated by a fine Ghaut, the Gairsoppa Ghaut, by which access is gained to the Gairsoppa Falls, a stupendous cataract; and to the Mysore country far beyond.

It has been necessary thus far to describe the physical aspect of North Canara, before proceeding to treat of the mode of tracing, which thick jungle and broken ground, made it desirable, and it may be said obligatory, to adopt.

Of the two, the labor of tracing a mountain road, is greater than that expended in the actual laying out of the sheer descent of the Ghaut itself, but it requires not a little scientific experience to pitch upon a general line for the latter, that will give scope for running a trace at a fixed gradient of 1 in 20, without having recourse to the clumsy expedient of zig-zags. Either a deep ravine or valley should be sought, up whose flank the road may be carried; or a long spur or series of spurs, round and about which it may wind, should be chosen: and where such a formation can be found, a combination of both features is best. Much deliberation and care has to be exercised at the outset, in judging by the eye of the practicability of the site chosen for the descent. The jungle is so close in North Canara, that a trial trace cannot well be run without great loss of time and useless expenditure of labor; all which is saved by having the ground reconnoitred by an experienced Engineer, who, with the help of the Aneroid Barometer, can pretty accurately settle the question.

The head of the Ghaut is usually a fixed point; and if it is not left open to doubt that it *must* be adopted in any case, the tracer may commence his line, working downwards, wherever his levelling staff carries him; recollecting he must ease off his slope a little when turning corners, and must cross all streams at a dead level. Once he has started, it is impossible to lay down fixed rules for his guidance, and there is frequently an ample field for the display of ingenuity and talent before he reaches the level ground beneath; in truth to pilot his instrument through the Canara forests, calls for the involuntary application of not a few principles of the inductive philosophy.

For such work, in such a country, it may be imagined the common Spirit Level is eminently unsuited. Weighty to carry, and cumbrous to set up in position, where the operator can barely find room to stand; and where

a clear prospect of even a dozen yards in front of him, is not to be obtained without felling the scrub which hinders advance and obstructs the views; its use has been wisely discarded in Malabar and Canara.

The instrument employed, is, what is known as the Gunner's Quadrant, or level for setting mortars at their proper angle, modified a little. The long bar is fitted with sights at either end, and has a universal joint screwed on at its centre.

The Quadrant* is reversed from the position it occupies in the mortar quadrant; having the arc turned inwards, and the radius outwards towards the tracer. An armature, bearing a small spirit level at its side, and a vernier to read minutes at one end, works on the Arc, which to enable the level to be used for tracing either up or down hill without reversion, has an excess arc of some 5° on the upper side of its zero point. Seeing that an angle of 3° corresponds to a slope of 1 in 20, an arc of 90° is considerably in excess of the angular accommodation necessary in tracing roads, and Messrs Elliott, Brothers, might with advantage curtail this over balancing appendage: they might also put the spirit level in permanent adjustment.

The tracing quadrant is fixed to a light stick, shod with iron, of a length sufficient to bring the pinhole of the sight within easy distance of the eye. The stick should not terminate in a point, or the levels will be vitiated. Its base ought to be about one and a half inches in diameter.

The forward staff is rather longer than the foregoing, but has a fixed vane, painted white, whose centre is exactly the same height from the ground as the pinhole of the quadrant sight. The centre is denoted by a dot in the middle of a black horizontal line.

Furnished with this simple instrumental equipment, and accompanied by an intelligent man to hold the staff, a goodly lot of pegs, and half a dozen active men with bill-hooks, the tracer begins his toils. Having set his arc, the staff holder is sent on 50 feet or so, along a path rapidly cleared by the woodsmen aforesaid, and moved by hand-waving till the cross hairs and vane spot coincide; he using one eye to catch the vane, and the other to observe the bubble simultaneously. Thus peg after peg is driven, and the trace proceeds with a rapidity proportional to the clearness of the ground, and the necessity for preliminary examination.

* I regret that the writer has not sent a drawing of the instrument above described. If he will favor me with it in time it shall be issued to Subscribers with the next Number.—[ED.]

It is a great advantage to have the pegs as close to one another as possible; for the more there are, the less risk is there of the true slope being lost when the excavation commences: a beginner is apt to put in too few rather than too many.

A party of fifty laborers follow on the heels of the tracer, to open out a bridle path a yard wide.

The pegs thus laid down are on the centre line of the future road, and when opening the guage path, the laborers are careful to stretch a strong line from peg to peg; by means of which the gradient is rigidly worked to. Before excavating; an upper row of temporary pegs, 3 feet higher up the hill side than the centre pegs, is inserted to denote the edge of the cutting in a like manner with the aid of string. If all these precautions are attended to, an even path upwards of a yard wide is speedily formed, and the slopes are preserved for ever. If nothing further is done to it, this path itself is often an immense accommodation to both men and animals; while it enables the Engineer to see his way much more clearly than if he had to grope through the jungle without so safe a guide. Any improvement in direction which suggests itself, is staked out after a thorough examination of the trace, and it is not seldom that the adoption of a deviation here and there is advisable.

A road, it has been mentioned before, through the hilly district of Canara, is more troublesome to trace than the incline of a Ghaut. This is due to the difficulty of determining by the eye alone, how particular features had best be dealt with, and it requires a great deal of care and practise to escape committing mistakes in the choice of gradients, and thereby losing both time and temper from being obliged to do work twice over. As a general rule, the saddles, over which the road must go, are first inspected; and it often happens that a small depth of cutting at the top will enable them to be crossed without exceeding the limit of 1 in 20; then the most suitable sites for bridges are roughly fixed; and after these observations are taken, the bridle path is levelled in to the best of the tracer's ability and judgment. On moderately flat ground, when it is certain all the slopes are within 1 in 20, the instrument need not be used, but the line is ranged as straight as possible, the ground to a sufficient width on either side is cleared, and the side ditches are staked out, and excavated at once, enclosing the full width of the road between them.

It has been customary in Canara to widen the 3-feet trace to a width

of 12 feet the first season, as doing so permits pack bullocks or even a single cart to pass along. The surface of the road inclines outwards slightly, to let the water run off, and no drain is allowed to be put on the inner side. There is, however, a check or intercepting channel, 18 inches broad and deep, cut some 30 feet above the road, discharging across it at convenient spots.

Experience has shown that a 12 feet road is little injured by the rains.

The objectionable expedient of giving the road surface an inward instead of an outward slope, is, by unskilled persons sometimes resorted to, a method that results in the road being soon cut up and becoming a mere water-course.

During the second season, the building of bridges and culverts used to be begun, and the road was widened to its full dimensions of 18 feet for a district, and 21 to 24 feet for a trunk road.

Everywhere, in side cutting, an inner drain was added to a road wider than 12 feet; but the transverse section of the road surface was as nearly horizontal as possible, half of the drainage falling outwards.

Before closing the article, it is only fair to state, that the Engineer must be prepared to encounter great and unlooked for difficulties, while tracing in this otherwise favored locality. From some hitherto unexplained cause, the whole of the North Canara district is eminently feverish, except at a few places on the sea coast. There is also a very sparse population, estimated at about 137 to the square mile; but as the bulk of the inhabitants congregate near the coast, there cannot be a third of that number actual denizens of the jungle. In consequence, much has to be got through with imported labor, easily scattered if fever comes among the gang.

Then, operations have to be well nigh suspended from June to September, on account of the monsoon; and during April and May, when most of the laborers seek their homes to prepare and sow their lands.

Altogether, although interruptions to progress are frequent and vexatious, and the Engineer is subject to privations and discouragement, he may reckon on being rewarded by seeing a district, between the greatest cotton field in India and the sea, and which contains such a harbour as that of Sedashaghur, rise steadily day by day into an importance, that was long ago augured for it by the few Madras officials and Engineers, who isolated in great measure from their fellows and from sympathy, were in a position to know and appreciate, the magnificence of its scenery, the value of its varied products, and the necessities of its trade.—(1865.)

No. LXXXV.

DESIGNS FOR BOMBAY POLICE COURTS.

By Captain Fuller, R.E.

Memorandum.

The author's designs for the Fort and Mazagon* Police Courts were objected to by Government, as being too ornate for the purpose required, and because the accommodation was designed with the view to meet probable future requirements on the number of magistrates being increased, and it was decided that the buildings are to be designed to accommodate only the existing number of magistrates; and any increase in their number hereafter is to be specially provided for in other parts of the island. It is submitted that the ornateness or otherwise of a building should depend upon its locality, and not merely on the use for which it may be intended.

Specification.

Foundations.—Basalt, rubble, and chunam.

Plinth.—Basalt, rubble, and chunam, external face, with irregular breccia rubble (a light buff-colored basalt), finely pointed.

Walls.—Similar to the plinth, and faced in corridors on both sides with Breccia rubble.

Dressings, Casings, and Cornices; Columns, Bases, Capitals, Arches, Parapets, Gable, Copings, &c., of calcareous limestone, procured from Porebunder in Kattywar. The plinth coping or string, to be of cut breccia

* The design for the Mazagon Court being of a similar architectural character to that for the Fort Court, it has not been thought necessary to give both.—[Ed.]

instead of limestone, in open corridors, as such are subjected to great wear and tear.

Basement Floor.—Minton's floor, unglazed tiles, on (6 inches) bedding of rubble and chunam.

Upper Floors —Minton's floor, unglazed tiles, over Fox and Barrett's iron flooring, filled with concrete and sound proof.

Ceiling.—Stuccoed with cornices under Fox and Barrett's floors.

Roof Sloping —Galvanized corrugated iron over teak framing and tongued, grooved and bended $\frac{3}{4}$-inch planking. The iron to be pointed slate color, over two coats of red lead.

Roofs, Flat, over Corridors and Porches.—To be composed of 2-inch slabs of limestone over teak joists, 12 inches apart, with 2-inch concrete and polished Portland cement rendering.

Ridging.—Galvanized cast-iron with cresting in one casting, in lengths of about 3 feet, jointed, and of weight sufficient to tie on the ridges without screwing to the roof. Finials and bannerets of wrought-iron, painted maroon, and picked out with gilded points, &c.

Doors and Windows.—Teak, panelled or half panelled, and half glazed or Venetian, as required, according to the position in the building; sashes $1\frac{3}{4}$ inches thick and frames (5×4 inches). Venetian styles connected to battens by hinges to stop at a right angle.

Fanlights.—In Gothic tracery.

Ventilators —Those in gables to be with fixed Venetians, with an half inch lead on upper and inner edge, to throw back water thus.

Those in roofs to be double, with horizontal battens, as described on the exterior, and at about 9 inches, a second set of vertical (V) Venetians to be fixed; the corrugated iron extending to 6 inches behind the latter, when all rain that gets in will return by the corrugations, instead of coming into the building.

Piping —All requisite roof pipes, water-closet pipes, and water supply pipes, to be laid on and fitted with all requisite fittings, such as hydrants, bib, and ball cocks, &c.

Plastering.—All rooms to be plastered internally, angles and borders being got up in Portland cement; no exterior walls, or those in corridors, to be plastered on any account (the latter are considered as external walls.)

General Abstract.

c. ft.		Rs
1,31,768	Foundation and plinth, at annas 8 32 per foot, ...	68,519·36
4,69,805	Ground floor, at annas 7·1 per foot, ...	2,08,475·96
2,31,005	First floor of centre portion, at annas 7·1 per foot, ...	1,02,508 46
3,05,383	First floor of wings, at annas 7 27 per foot, ...	1,38,758·4
3,11,641	Second floor, centre portion, at 7·27 per foot, ...	1,41,601·88
14,49,602	Cubic feet, at annas 7·28 per foot deduced, ...	6,59,864·00

Detached Building.

4,88,945	Cubic feet, detached building, at 6 annas per foot, ...	1,83,354·00
	Grand Total, Rupees, ...	8,43,218 00

January 6th, 1865.

J. F.

No. LXXXVI.

THE SIND RAILWAY.

Description of the Line and Works of the Sind Railway. BY JOHN BRUNTON, M. Inst. C.E., F.G.S. *Abridged (by permission) from the Minutes of Proceedings of the Institution of Civil Engineers.*

So far back as the year 1842 Sir Charles Napier, the conqueror of Sind, acknowledged and publicly urged the vast importance of the valley of the Indus, as the route for military as well as for commercial communication with the Punjab and the North-West Provinces of India. He never ceased to press upon the Government the necessity of establishing new modes of conveyance, and pointed out Kurrachee, then but a small fishing town, as the port to which the traffic would infallibly tend. Acting on this conviction, and as a first step towards carrying out these enlightened views and improving the port of Kurrachee, Sir Charles Napier designed and commenced the long mole across the tidal marsh, which separates the town of Kurrachee from Keamaree. This mole still bears his name; and at the point to which it had been carried when he left Sind, and from which he embarked on that occasion, a small obelisk is erected recording these facts.

Nor has Sir Charles Napier been the only eminent man who has pointed out the natural advantages of the valley of the Indus, as the route of communication with the Punjab and the North-West Provinces of India. Amongst the many who have recorded their opinions on the subject may be mentioned Lord Dalhousie, Sir Henry Pottinger, Sir John Lawrence, Sir Justin Shiel, General Jacob, and Sir Bartle Frere.

In the year 1849 the Government recognised the necessity of introducing into India the improvements in communication which were offered by railways; and the two great lines,—the East Indian and the Great Indian Peninsula,—were inaugurated, with a view to open up the districts having the two great ports of India, Calcutta and Bombay, as the outlets for their produce. The success which attended the guarantee system, as affording facilities for raising the capital for Indian railways, was at once evident, and the importance of extending it to other districts was acknowledged.

Attention was immediately drawn to the Indus Valley route, having Kurrachee as its sea terminus; and a concession having been granted to Mr. W. P. Andrew in 1855, a company was formed, called the Sind Railway Company, but embracing under its management not only the Sind Railway proper, or the line from Kurrachee to Hydrabad upon the Indus, but the Punjab line, from Moultan to Lahore and Umritsir, and a flotilla of steam boats on the river, with a view to complete the through communication. Three distinct capitals were originally raised, under the following titles:—1, The Sind Railway; 2, The Indus Steam Flotilla; and 3, The Punjab Railway. The accounts of these sections are kept perfectly distinct, while economy and harmonious working are secured, by the concentration of the management in the hands of one board of directors. Another section of this great scheme has since been intrusted by Government to the Sind Railway Company. It is called the Delhi Railway, being an extension of the line from Umritsir to Delhi, where it will form a junction with the northern terminus of the East Indian Railway. The lengths of these sections are respectively:—Sind Railway, from Kurrachee to Kotree, on the Indus, 108 miles; Indus Steam Flotilla, Kotree to Moultan, 570;* Punjab Railway, Moultan to Lahore, 222, Lahore to Umritsir, 32 = 254; Delhi Railway, Umritsir to Delhi, 300. Total, 1,232 miles.

It is to the construction of the first section of the line, between Kurrachee and Kotree, that this paper is specially devoted. Although this section of the entire system is the shortest, it constitutes, as has been graphically observed, "the neck of the funnel." Over it must pass, not only the whole of the existing traffic, but as the other sections are com-

* This distance being measured upon the river is, on account of the windings, fully 100 miles more than the direct line by land.—J. B.

pleted, the developed commerce of this vast territory, hitherto locked up, will pour in upon it, taxing its capabilities as a means of communication, and, doubtless, realising the sanguine anticipations of its promoters.

Kurrachee, the western terminus of the railway, is situate in lat. 24° 47′ 21″ and long. 66° 58′ 15″, and is not only the natural port of Sind, but also of the Punjab and of Central Asia. Like many other land-locked harbours, it has the disadvantage of a bar at its mouth; but, nevertheless, the depth of water upon the bar at ordinary tides is sufficient to admit ships drawing 17 feet to 18 feet, and at spring tides, ships drawing 21 feet have passed in with safety. When once within Manora Point the depth of water is much greater. The fast-increasing traffic of the port, and the large size generally of the vessels trading there, demanded that some measures should be taken to increase the depth of the water over the bar, thus rendering the entrance to the harbour available at all seasons; and that, by the erection of wharves and other appliances suggested by modern science, greater accommodation should be afforded. With this view her Majesty's Government, in 1856, applied to the late Mr. James Walker, F.R.S. (Past-President Inst. C.E.), for a Report upon the subject; and in 1858 he submitted plans, sections, and estimates for various suggested improvements. These recommendations were accepted by the Government, and immediate steps were taken for carrying them out. There is no doubt that when the works in progress are completed, Kurrachee harbour will take a high rank as a safe and commodious port.

The population of the town of Kurrachee is about 60,000, and is rapidly increasing. The principal articles of export consist of oil seeds, and grain of all sorts, wool, cotton, hides, indigo, munjeet, drugs and dyes, raw silk, fruit, and saltpetre. The import trade comprises cotton piece goods, woollen goods, malt liquors, railway materials, metals, wines and spirits, tea, coffee, timber, pipe staves and casks, regimental necessaries, spices, fruit, oilman's stores, and wearing apparel. The value of the trade for 1862-63 was estimated at £5,000,000.

Within the last few years, a large number of European and native mercantile firms have established themselves in Kurrachee, and have erected extensive warehouses, in order to meet the rapidly increasing trade of the port. Her Majesty's Government has found it necessary to erect a new and more commodious Custom-house; and the harbour improvements

now in progress, include not only the deepening of the water on the bar, but greatly extended wharf and quay accommodation. The Sind Railway will communicate directly with these wharves and landing places, and a great improvement in the system of loading and discharging cargoes has already been introduced, and is daily making rapid strides.

Hitherto all commercial communication with the upper districts has been carried on by native boats on the Indus, or by *kafilahs* of camels. No roads worthy of the name exist. Until the opening of the Sind Railway these river boats were accustomed to stop at Khettie, a river station at one of the mouths of the Indus, and there discharge their cargoes into native sea-going craft, which conveyed the greater part to the port of Bombay, only a comparatively small portion reaching Kurrachee. The import trade had to struggle with the same impediments, increased by the slow progress made in "tracking" the boats up the Indus, against an average current of 3 or 3½ miles, per hour, and a portage at Sukkur of 1½ mile. During the prevalence of the south-west monsoon, lasting from May to September inclusive, even this wretched and dilatory system was suspended, paralysing commerce and creating an indescribable amount of expense, inconvenience, and irregularity. The formation of the Sind Railway, and the improvement of the port of Kurrachee, have met all these obstacles, and will open up a magnificent field for commercial enterprise, introducing civilisation, with all its attendant benefits, to a district inhabited by millions of human beings hitherto shut out from its influences.

On the 29th of April, 1858, the works of the Sind Railway were commenced by Sir Bartle Frere, K.C.B., then the highly-respected Commissioner of Sind, who wheeled the first barrow-load of earth into an embankment in the neighbourhood of Kurrachee. The contract for the execution of the whole of the works was originally let to Messrs. James and Edwin Bray, but in June, 1859, the line was taken over by the Company, and the works then remaining to be completed were executed departmentally by the Engineers, Inspectors, and other officers of the Company. Without entering into a statement of the causes of Messrs. Bray's relinquishing the works, it will suffice to say, that when the Company's Engineers took possession of them, they had to encounter difficulties which were not due entirely to the peculiarities of the country. There was a great dearth of the ordinary railway plant: irregularity in the payment of the native laborers of all classes had driven many away, and

had caused an unnatural and serious rise in the rate of wages. To meet this position of affairs, and to secure the economical execution of the works, a fair tariff of wages, at a reduction of fully 25 per cent. upon those which were paid by Messrs. Bray, was published by the Company's Engineers, and daily payments were guaranteed. This had the effect of drawing a considerable number of laborers to the undertaking.

The Province of Sind contains but a sparse population, which is principally located on the low-lying alluvial land on the banks of the river, where the rich earth yields ample returns with a minimum amount of labor. The Sindee, born and bred on these plains, is naturally indolent and devoid of muscular power; at the same time he is not deficient in talent, easily acquiring a knowledge of account-keeping and writing. The natives of the neighbouring state of Cutch are a much superior race. Cutch sends carpenters, masons, smiths, and skilled handicraftsmen to the whole of the northern portion of the Bombay Presidency; and from thence came a large majority of the skilled workmen employed on the Sind Railway. From the hill tribes of Beloochistan and Afghanistan were obtained a hardy race of laborers; men of great stature and personal strength, but wholly ignorant of the use of other tools than the *phowrah*, (a large kind of hoe,) and a basket in which to carry the loosened earth. Half-wild and unaccustomed to the restraints of a more civilized state, these men required much tact, and at the same time a strong arm, to keep them in order. To secure and maintain discipline amongst such a body of men, it was found advisable to organise a regular railway police force, consisting of about 80 men. Police stations were erected at intervals along the line. To facilitate the administration of justice the Government appointed a special magistrate, whose duty it was to move up and down the line, and to hear any cases which might be brought before him. To these wise precautions may be attributed the fact, that few outrages of a serious character occurred, the majority of cases being petty thefts and attempts at imposition. This facility for obtaining justice, and the rapidity with which punishment followed crime, were highly appreciated both by the Europeans and the natives.

In districts like Sind, where the population is scanty, and it becomes necessary to depend upon distant provinces for the supply of labor, it is obviously wise policy to offer every inducement, not only to secure, but to maintain such a supply. A higher rate of wages than ordinary may, in

the first instance, draw together large bodies of men, but other arrangements are absolutely essential for establishing contentment and permanence. Hardy as these Beloochees and hill tribes were, and unaccustomed to anything approaching luxury, they appreciated highly such attentions to their feeding, shelter, and health, as policy no less than humanity suggested. When it is borne in mind, that the course of the line of railway lay at a considerable distance from existing towns, or villages, only passing through the small village of Jemedar-ke-Landi, and leaving the important towns of Tatta and Jerruck at distances of 10 miles and 17 miles respectively,—it will be seen, that a difficulty arose in obtaining food for the large masses of men congregated at the various heavy portions of the works. This was met by the Company licensing a number of *buniahs*, or native provision merchants, to establish themselves at various points along the line; their scales of charges being regulated by a *nerrick*, or list of prices, settled by the nearest *kardhar*, under the orders of the railway magistrate. To supply the workmen with wholesome water for drinking was equally imperative. When this precaution was not observed, the men were under the necessity of using such water as was most easily accessible, and as it was generally of very bad quality, the results were cholera and and fever of a bad type. A regular system of water carts and bullocks was first organised, and as the railway progressed, water trains were dispatched from the Mulleer, the Indus, and the Bahrun, to meet the daily requirements of the men. It was remarked, that a supply of wholesome water was always followed by the disappearance of the diseases abovementioned, and more particularly of fever. To protect the men from another source of fever, mat huts were erected, which sheltered them from the heavy dews, and rendered them more comfortable and contented. To afford medical aid in cases of sickness, or of accident, permanent hospitals were erected at Kurrachee and Kotree, under the charge of the civil surgeons of these stations; and in addition, two temporary hospital buildings were erected at Joong Shaie and Doraji Gore, under the charge of a resident apothecary. These arrangements were very successful in preserving the health of the employés of the Company, both European and native, and in cases of accident, they were doubtless the means of preserving many lives.

The natives work in gangs, under a self-elected *muccadum*, or ganger, whose orders they cheerfully obey, and to whom each man pays a stipula-

ted small per-centage from each rupee earned by him. It is through the the muccadum, that all agreements are made for works, and it is he who receives the amount of the earnings for division. There exist also, in Sind and in the neighbouring States, native landholders who by inheritance, are chiefs of large districts of country, and are recognised by Government as possessing a sort of feudal right therein. They are heads of clans, and as there is no longer any necessity for summoning their vassals for defence, or for other less lawful objects, they find it their interest to use their power for the purpose of supplying laborers to any large public work, receiving a small remuneration in the shape of head money. In the year 1856, while acting as Commissioner in Sind, during the temporary absence of Sir B. Frere, General Jacob, recognising the demoralising influences which attended the system of compulsory labor, proclaimed all labor in Sind to be free. This edict is highly prized, though sometimes taken advantage of and abused, by the laboring classes.

The departmental execution of the work gave the Engineers and other officers engaged, favorable opportunities of becoming acquainted with the capabilities of the various classes of natives, as well as of ascertaining the cost of each description of work. When work of any kind was executed by day labor, it was found that its economical execution entirely depended upon the energy and honesty of the muccadum, or native overseer; but these good qualities were so rare, that it become necessary to resort to the piece-work system. It was with some difficulty that this was established as a rule; but by degrees opposition was overcome, and the earthwork, masonry, and ballasting, were let to small gangs, with considerable advantage to the Company, while the laborer himself, excited to more vigorous and diligent exertion, earned higher wages than by the day-work system.

The following are the average prices paid for earth and rockwork along the line:—

Alluvial earth excavated from side trenches and placed in embankment, the average distance of conveying it being 22 yards, . . .	10 annas per 100 cubic feet, or 4·09 pence per cubic yard.
Firmly set gravel, or soft shaly material, . .	12 annas per 100 feet, or 4·9 pence per cubic yard.
Rockwork requiring bars, but no powder for blasting, ...	1*s.* 9*d.* per cubic yard.

Hard rock requiring blasting,—the powder, drills, and other tools being found by the Company, .	2s. 0d. per cubic yard
Ballast, consisting of small stones, or gravel, gathered in the neighbouring jungle, selected and placed *in situ*, ...	1s. 0d. „ „
Ballast of broken stone, ...	1s. 10d. „ „

The total quantities of the different classes of work executed upon the line, and the average cost of each kind, inclusive of the cost of the provisional staff of superintendents, but exclusive of that of the permanent Engineering staff, are given in the following Table:—

Description of Work.		Quantity.	Average Cost £	s.	d
EARTHWORK.					
Embankments, ...	cubic yds.	1,831,916	0	0	11½
Cuttings (a large portion consisting of rock of different degrees of hardness, . . .	„	432,705	0	1	6¾
Diversion of roads and streams, ...	„	212,532	0	0	8½
Ballasting, ...	„	408,596	0	1	6
Pitching slopes, ...	sup. yds.	1,745	0	2	0
PERMANENT WAY.					
Leading and laying, ...	lineal yds.	193,600	0	6	0
FENCE WALLING, ...	„	338,700	0	3	0
MASONRY.					
Concrete, ...	cubic. yds.	10,756	0	4	6
Dry rubble, ...	„	2,526	0	3	0
Common ditto, ...	„	17,434	0	12	0
Coursed ditto, with rubble backing, ...	„	352	0	15	0
Coursed ditto, ...	„	32,550	1	0	0
Block in course, ...	„	15,192	1	11	6
Ashlar, ...	cubic feet.	87,806	0	1	7½

The geological character of the district traversed by the Sind Railway demands a few remarks. The aspect of the country generally is barren in the extreme, but in some places there is sufficient soil to repay cultivation. Situated in what is termed the rainless zone, the average quantity of rain is very small, not amounting to 5 inches annually. Except during the rainy season, the river beds are dry, but in them water can generally be obtained, by sinking to depths varying from 5 feet to 30 feet. All the water procured from these wells, is, however, more or less saline.

In the neighbourhood of Kurrachee, the principal features of the country are low hills, varying from 150 feet to 200 feet in height, and

consisting of a coarse-grained arenaceous rock, of a dirty yellow color, abounding with fossils. Most of these hills are capped with conglomerate, more or less disintegrated on the surface, the pebbles composing it being water-worn, and the majority derived from the nummulitic limestone of the Halla range of hills, which extend from Cape Monze, in a north-easterly direction, to the west of Mithun-Kote on the Indus. All the hills lying north of the Indus to the foot of the Halla range, of which they are spurs, exhibit the effect of considerable volcanic disturbance, and the drainage of the country passes through the fissures thus formed. One of the most remarkable of these is at Dhurwat, where, during the rains, the water of the Bahrun occasionally rises 70 feet, rushing through the pass with overwhelming force. The Kheytriani hills are composed of pale arenaceous limestone, containing but few nummulitics. This rock is easily worked, and is an admirable building stone, hardening with exposure. It was from quarries opened in this neighbourhood, that most of the stone was obtained for the masonry of the Central district of the line. Near the Rhodh river there are many small hills, of conical shape, composed of calcined clays of various colors, and also large collections of nodular masses of flint In the aluminous clay beds, veins of foliated gypsum abound. In the plains lying between these hills the soil is alluvial, and in many places it is covered with boulders of nummulitic limestone and conglomerate.

The distance between Kurrachee and Kotree traversed by the Sind Railway is 108 miles 10 chains. Of this distance 32 miles 50 chains are level, and the remaining 75 miles 40 chains are on inclines more or less favorable, 1 in 200 being the ruling gradient.

The total length of straight line being 74 miles 22 chains, the length of the line on curves is, therefore, 33 miles 68 chains, the sharpest curve having a radius of 43 chains for a distance of 76 chains.

Considering the nature of the country traversed by the line, these may be considered favorable features, and place it in a good position for being worked at a moderate cost.

The earthworks generally are executed to accommodate a single line of railway; but all the bridges, culverts, and stone viaducts are constructed to carry a double line. In the cases of the wrought-iron viaducts, the stone piers are adapted to support girders for a double way, while those required for a single line alone are erected. The only portion of double

line yet made, is that between the workshops at Ghizree Junction and the terminus at the Bunder Head, a distance of 3 miles 15 chains. In order to accommodate the traffic coming to Kurrachee from the districts called the Eastern Delta of the Indus, during the south-west monsoon, a short branch, $3\frac{1}{2}$ miles in length, has been constructed, leaving the main line near the workshops, and terminating in an embankment and a timber pier at Ghizree, alongside which native boats discharge their cargoes.

The Permanent Way consists of the ordinary double-headed rail, weighing 65lbs. per yard, fixed by compressed wooden keys in chairs, each weighing 22lbs. The joints are fished in the usual way, the fish plates being secured by four bolts, each 1 inch in diameter. The whole is laid on transverse wooden sleepers, at intervals of 3 feet, except at the joints, where the sleepers are only 2 feet apart. The dimensions of the sleepers are:—length, 10 feet; breadth, 10 inches; depth, 5 inches. A large proportion of the sleepers is of red and white pine creosoted, sent from England. To complete the requisite quantity, a contract was entered into with a native merchant at Lahore, for the supply of sleepers of Deodar timber, (*Cedrus deodara*,) which grows upon the slopes of the Himalayas, where it attains great size. Several logs sent down to Kotree for the use of the railway measured 5 feet in diameter at the butt, and a calculation of the taper upon the log gave a result of 150 feet as the height of the tree. The trees are felled, and cross-cut into convenient lengths, for rolling to the bottom of the ravines, on the banks of which they grow. The private mark of each proprietor is cut on every log he has felled. These logs remain at the bottom of the ravines until the rains, when they are carried by the torrents into the River Indus, where they are watched for, selected according to the marks, rafted and floated to their destination. This rough treatment wastes much of the timber; many of the logs are split, and the ends of all are damaged; while the shortness of the pieces, which vary from 20 feet to 33 feet in length, diminishes their value. Owing to the deficiency of rain in the season of 1859-60, only a small quantity of this timber could be got down. The native merchant thus failed to complete his contract; and a quantity of Australian blue and white Gum, and native red Eyne sleepers was, therefore purchased. These were objectionable, on account of their great weight, and the ease with which they were split by the driving of the spikes. The respective cost of each, when delivered in Kurrachee or Kotree, was:—

	Delivered in Kurrachee.	Delivered in Kotree.
	s. d.	*s. d.*
Creosoted pine,	8 11	...
Australian blue gum,	8 0	...
Eyne, a native timber,	7 9	...
Deodar,	...	6 0

The value of the deodar timber is becoming rapidly recognised, and means will doubtless, be adopted for supplying it in longer lengths, and in greater quantities. When first cut it possesses a very strong scent, which it retains for some years; and to this probably may be attributed its immunity from the ravages of the white ant, which does not attack it until the timber has to a great extent lost this scent. To protect the deodar sleepers from these attacks, and before the Burnettising apparatus was received from England, they were steeped in a solution of sulphate of copper. This proved to be an unfailing specific; but it possesses this serious objection, that iron nails or spikes driven into timber thus prepared are rapidly destroyed by the action of the sulphuric acid. The result of the Author's experience, with reference to the important question of sleepers, is that pine sleepers, whether red or white, imported from England and creosoted, are liable to split and twist to a great extent, probably on account of the extreme dryness of the climate. They also become very brittle, the nature of the timber being destroyed. The creosoting process only penetrates a certain distance from the surface of the sleeper; and so long as the sleeper does not split, the creosote effectually protects it from the attacks of the ant, but immediately a part of the interior becomes exposed, the ant attacks it, and soon destroys the uncreosoted core of the sleeper. Hitherto, the necessity for replacing sleepers has mainly arisen from their giving way by splitting, rather than from any damage by the attacks of the white ant, or from ordinary decay. The excellent ballast on the Sind Railway, consisting chiefly of broken stone or clean gravel, assists in preserving the sleepers from the white ant.

The cost of creosoting sleepers in India varies with the description of timber submitted to the operation. In 1854 Mr. Turnbull, Chief Engineer of the East Indian Line, gave the following summary of the details of the cost supplied in a former portion of his Report:*—sâl, $6\frac{1}{2}d.$; teak, 1*s.*;

* *Vide* "Selections from the Records of the Madras Government. Report of the Railway Department for 1854," page 238.

soondri, 1*s.* 5½*d.*; and sissoo, 2*s.* 1½*d.* per sleeper. He further states, in the same Report, that one thousand sleepers of fir wood, prepared by Sir W. Burnett's process with chloride of zinc, were landed and stacked in Calcutta, where they remained for two years. On being examined at the end of this period, they were all found to be sound, and in as perfect a condition as when they were landed This statement led the Author to recommend the adoption of Sir W. Burnett's process, and a complete apparatus was shipped from England. The vessel was, unfortunately, lost on the passage; and considerable delay occurred in replacing the apparatus, so that the majority of the deodar sleepers were submitted to the sulphate of copper process. The cost of the Burnettising process at Kotree is 5½*d.* per sleeper, which contrasts favorably with the cost of creosoting

The forests of Sind consist chiefly of Babool, a species of acacia, of which there are two kinds, red and white, so named from the respective colors of the heart-wood. The former is by far the more valuable of the two, as it is extremely hard, and resists the attacks of the white ant. This timber is used by the natives for the manufacture of carts and Persian wheels; but as it is very crooked, it is not available for railway sleepers A few pieces of timber were carefully selected, and accurately gauged to size, with a view of testing their comparative strengths, but the experiment was not carried out When thoroughly seasoned, the following comparative Table of the weights of each kind was obtained :—

Red eyne,	56¼ lbs	per cubic foot.
Jarrah (Australian mahogany,)	52¼ „	„ „
Common jungle teak,	34½ „	„ „
Moulmein teak,	33¾ „	„ „
Deodar,	31½ „	„ „
Yellow pine,	24¾ „	„ „

Neither eyne nor jarrah timber will float in sea water before it is thoroughly dried. Red eyne is obtained from the forests of Guzerat, and costs in log, delivered in Kurrachee, about 1*s.* 6*d.* per cubic foot. It is not, however, very plentiful. As a pile it drives remarkably well, hardly requiring either ringing or shoeing in ordinary ground. It is reported to be impervious to the attacks of the white ant; but of this the Author has no positive proof. The Moulmein, or Rangoon teak, judging from the quality of the best the Railway Company could procure, is inferior to

the southern, or Malabar teak, which, however, is scarce and expensive. The cost of Moulmein teak in log, delivered in Kurrachee, varies from £15 to £18 per load. The jarrah is a fine Australian timber, and is obtainable in logs of large scantling and length. If not well seasoned before being submitted to the dry climate of Sind, it cracks and rends seriously, but not so if it is allowed to season for twelve months before being shipped. Its cost in Kurrachee, is about 1*s.* 6*d.* per cubic foot. The deodar timber, the qualities of which have been before adverted to, costs at Kotree in log, about 1*s.* 1*d.* per cubic foot.

The majority of the Fencing used on the Sind Railway consists of a dry rubble-stone wall, having a coping of stones on edge, set in mortar. Its height is 4 feet above the surface of the ground. Its thickness at the bottom, just above the footings, is 1 foot 10½ inches, and at the top 15 inches. Its average cost was 3*s.* per lineal yard Along 15 miles of the line, between Jemedar-ke-Landi and Guggur, five-strand wire fencing was adopted, on account of the distance of suitable stone, and the necessity for its rapid completion. Its cost was 2*s.* 4½*d.* per lineal yard. The cost of maintenance of the wire-fencing is high, compared with that of the stone wall.

At Kurrachee, the locomotive erecting and repairing shops are built, at the junction of the Ghizree branch with the main line. These works consist of a sawmill, smiths', fitters', heavy and light tool shops, iron and brass foundries, with engine and carriage-erecting shops, all furnished with the requisite machinery, and with tools driven by engine power. Previous to the establishment of these works, there existed no means, nearer than Bombay, for the execution of the necessary repairs, or the construction of the numerous articles required by a railway; and even Bombay offered but few facilities, and those involving great expense. Hence the necessity for pushing forward these works, which in the formation of the line, proved to be of great assistance in the manufacture of plant, &c. The organisation of these works, with a view to their ultimate utility, and at the same time, with a due regard to economy, formed an important consideration and was surrounded with many difficulties. To man these shops entirely with European workmen would involve an enormous cost; it became necessary, therefore, to call in native assistance, as far as practicable. The Cutch carpenters and smiths, as has been before remarked, are intelligent and excellent workmen; but they were wedded to the use of their own

rude tools, in their own fashion, involving great delay in turning out work. Their usual method is to carry on all operations while seated on the ground; and, in the case of the carpenters, to make almost as much use of their toes as of their fingers. It became, therefore, the duty of the English foreman to induce them, first of all, to stand to their work, and then, to teach them the use of European tools. This has been accomplished by degrees, and the result has been most satisfactory. The carriages now framed and erected at these shops, entirely by Cutch carpenters, display workmanship which would be a credit to the best European manufactory. It is found necessary still to employ two European smiths for heavy and important work.

To keep up a supply of European foremen, fitters, engine erecters, and engine drivers, the system of taking apprentices in the workshops has been adopted. The following liberal terms were offered:—

During 4 months' preliminary trial, per mensem,			.	4	rupees or	8s.
First year from date of indentures,		,,	.	30	,,	£3
Second,	,,	,,	.	40	,,	4
Third,	,,	,,	.	50	,,	5
Fourth,	,,	,,	.	60	,,	6
Fifth,	,,	,,	.	80	,,	8

In India there are many intelligent lads, sons of European soldiers and of men employed in various departments of the Government service as clerks, &c., who are educated in the regimental and Government schools: these lads and their parents are very glad to avail themselves of the opening thus offered for learning a trade, and obtaining substantial employment. By this arrangement a staff of men, thoroughly acclimatised, is being educated in all branches of railway mechanism, and without doubt great advantages will, in a few years, accrue therefrom.

The Electric Telegraph, with two lines of wires, is laid along the Sind Railway. The wires are carried upon posts of deodar timber, fixed in cast-iron sockets. The block system of working the trains is adopted. Needle-speaking instruments are used for conveying the information required between the several stations and passing-places. On the Continent of Europe there exists but little difficulty in obtaining suitable and intelligent clerks for working the telegraph signals; but in India the case is widely different. There, for the sake of economy, the staff of telegraph clerks is formed and recruited from the class of half-castes and more intel-

ligent natives, very often lads of fourteen or fifteen years of age. It is true they have to pass a preliminary examination as to their capabilities in writing and reading English; but the Author's experience of men who have passed this examination is, that they are often deficient in the important point of understanding the messages they transmit or receive. This becomes a more serious matter when the signalman, a native, is trusting to the verbal instructions he receives from the telegraph clerk, who, in several instances on the Sind Line, holds the combined offices of telegraph clerk and station master, a system which, for many obvious reasons, is to be deprecated. Greater security would be obtained by the separation of the train-signalling machine from the conversing telegraph, and also by the introduction of permanent train-signals, which would speak to the eye, and could not be liable to misinterpretation. Native clerks are too apt to occupy the speaking-machine, and at the same time to amuse themselves with a conversation, to the exclusion or the delay of important messages.

In India train-signalling stations on which depend the proper and safe working of the trains, are often in isolated situations, and economy only allows the maintenance at each station of one signalling-clerk; who may often be taken ill with fever, or otherwise be rendered unable to perform his duties. The reduction of the train-signalling to as simple a system as possible, and the training of all policemen and inspectors in the use of the instrument for this purpose, would be attended with much benefit.

The line of the Sind Railway, as will be seen by the map, crosses the natural drainage of a great extent of country, thus rendering necessary a large provision for waterway. The rains in Scinde are very partial, and as there are no records of rainfall which throw much light upon the subject, and no existing bridges, a careful examination of the old flood marks was the only guide as to the requirements. Fixing the spans of the bridges at the large rivers and nullahs was comparatively easy. It was in crossing wide, flat plains, such as that at Pipri, that the question was surrounded with difficulties. This plain is nearly 5 miles wide. A certain number of culverts was originally built, and in addition, large catch-water drains were cut, with a view of conducting the rain water to the Guggur river, the natural and main drain of the valley. In 1861, when the rain was very heavy for about six hours in this locality, the drains were found in-

sufficient to carry off the water in the time, and the embankment of the railway, which ponded up the water, was soon breached in many places. To remedy this, it was considered a waste of money to erect more culverts; but the plan was adopted of lowering the line to the surface, laying it, in fact in a ditch 16 feet wide and 2 feet deep, just large enough to receive the ballast, and allowing the water to flow over the line. This plan was severely tested in the unusually heavy rains of 1862, when the water passed over the rails to the depth, in some places, of 9 inches, without either damaging the line, or stopping the traffic. In districts like Sind, where the rainfall is so partial, and of such short duration, but at the same time so heavy, it is submitted that this mode of crossing a large, flat plain is the safest and most economical.*

The scarcity of pure water fit for use in the locomotive engines, except at a few points, caused considerable trouble on the first opening of the line. The watering stations are nine in number. The salts, which the water obtained at these stations held in solution, differed materially, and the consequence was, that if an engine started for Kotree, and took in water at Jheem Peer, or Joong Shaie, priming occurred to a serious extent; but this was not the case if water was taken at the Bahrun. As the water at these stations was considered fair drinking water, and as there was nothing in the taste to induce the suspicion that they might not be used indiscriminately for locomotive purposes, it would appear desirable, that a careful analysis of the water obtainable along a line of railway in India should be made at an early stage of the operations. The Author has arranged that the waters used and obtainable upon the Sind Railway should be analysed, and when combined with a report upon the effects produced in the locomotive engine by mixing them, some useful information will be obtained for guidance in parallel cases.

The haulage of materials constitutes an important item in the cost of the construction of railway works everywhere, and especially in India. The following facts will assist in forming calculations on this head. About 5,500 tons of permanent way materials were required at Loyach, one of the stations on the line, and were conveyed by native boats from Kurrachee to Soondah, a point upon the river Indus where there was a convenient landing place. It was necessary to form a road for carts between Loyach

* The same system has, I believe, been adopted on the Umballa and Kalka road.—[Ed]

and Soondah, through the jungle, a distance of 12½ miles, and the following were the details of the cost of the whole proceeding.—

Freight from Kurrachee to Soondah by native craft, including cost of loading and discharging cargo, . . .	8*s.* 6*d.* per ton.
Loading and unloading the native carts, ...	0*s.* 6*d.* ,,
Haulage 12½ miles, at 1*s.* per ton per mile, . . .	12*s.* 6*d.* ,,
The cost of forming and maintaining the road for twelve months was £323 13*s.* 6*d*, equal on the above-mentioned quantity of materials to, ...	1*s.* 2¼*d.* ,,

The following is a list of the different sized culverts erected on the line, distinguishing the number of culverts, and the number of openings of each size:—

Number.	Size of Opening.	Number of Openings.
46	2 feet 6 inches,	191
2	3 ,,	2
2	6 ,,	2
113	8 feet 6 inches,	329
5	10 ,,	9
18	12 ,,	53
2	15 ,,	2

The line of rails was carried over the openings of 2 feet 6 inches, by placing ordinary sleepers upon stone piers, the rail itself bridging the opening. Though this appears to be an economical mode of obtaining waterway through low embankments, it was found that the vibration of the line was communicated to the piers, which, though very carefully built, thus required frequent repairs, and in some cases cramping. Whenever the height of the embankment would admit of it, and to secure the largest amount of waterway, openings of 8 feet 6 inches were extensively introduced. In such cases the ordinary permanent way was carried upon teak timber beams, 12 inches square in section, supporting a platform of planks 4 inches thick below the sleepers, to carry a thin layer of ballast, protecting the platform from fire, and forming a footway across the openings. The timber in these culverts was carefully paid over with dammer, or pitch, laid on very hot. This process protects the timber from the attacks of white ants, but it is objectionable on account of the inflamable character of the material. The other culverts in the list were built of stone, with pitched inverts and aprons.

The bridges along the line are of the following number and general dimensions:—

19	bridges,	containing	48	arches,	each of	20	feet span.
1	"	"	3	"	"	30	"
2	"	"	10	"	"	40	"
2	"	"	4	"	"	45	"

The large stone viaduct across the Bahrun river is 1,728 feet in length. Its greatest height, measuring from the bed of the river to the rails, is 31 feet 6 inches, and its average height is 25 feet 6 inches. The superficial measurement of the bridged area is 44,064 square feet. It consists of thirty-two arches, each 45 feet span, and having a rise of 10 feet 6 inches. This was the heaviest piece of masonry upon the line, and the time required for its completion was the measure of that for the opening for public traffic. The quantities of the different classes of work in this viaduct, and the average cost of each kind are as follows:—

	Quantity.	Cost.
		s. *d.*
Excavation of foundations,	20,513 cubic yards	0 9¼ per cubic yd.
Concrete,	6,814 "	4 0¼ "
Common rubble,	4,455 "	11 9¾ "
Coursed rubble,	7,233 "	20 0¾ "
Block in course,	5,244 "	31 6 "
Ashlar,	29,000 cubic feet	1 3 per cubic foot.
Broken stone for backing and filling in between the spandrils,	2,650 cubic yards.	
Ballast,	3,780 "	

The total cost of this viaduct was £27,185 12*s.* 10*d.* The cost per lineal foot of viaduct was £15 14*s.* 7*d.*, and per square foot of bridged area 12*s.* 4*d.* The viaduct was commenced on the 5th of March, 1859, and a locomotive engine ran over it on the 26th of January, 1861. The work was thus completed in twenty-two months and a half.

There are six viaducts with iron girders. The girders sent out from England were on Warren's principle, of 80 feet clear span. These were erected at the following rivers:—

The Mulleer,	21	spans.
" Guggur,	3	"
" Dorbagi,	2	"
" Runnpittiani,	6	"
" Loyach,	8	"
" Rhodh,	3	"
Total,	43	"

With regard to the Mulleer Viaduct, the most extensive of this class, the Author would merely observe, that the foundations and general construction were of an interesting character, on which he abstains from enlarging as he finds that Mr. J. E. Hartley, (M. Inst. C. E.,) who was the Resident Engineer during its construction, is engaged in writing a special Paper upon it. From the experience acquired by the Author from these examples of Warren's girders, he is compelled to report unfavorably of them, when contrasted with plate girders. There is an amount of vibration, both laterally and vertically, caused by passing trains, which had the effect of breaking, or of loosening the bolts fixing the longitudinal timber stringers to the cross girders. To such an extent did this occur, that it was found necessary to appoint one, two, or three native workmen at each viaduct, according to its length, whose duty it was to inspect and repair these breakages, or loosenings, after the passage of each train. The cost of this was so serious, that it was found advisable to take up the original rails, and although it raised the line and interfered slightly with the gradients, to lay the ordinary permanent way upon transverse sleepers. This has had the effect of diminishing the evil, but not of removing it entirely. The arrangement of the timber platform over these viaducts the Author considers highly objectionable, inasmuch as while loading the bridges, it adds nothing to the lateral stiffness, nor does it distribute the load over the whole area, as might have been the case. It is submitted that two layers of planking, each $3\frac{1}{2}$ inches thick, laid diagonally, and crossed, upon which the ordinary permanent way could have been laid, would have been a better arrangement,—stiffening the bridge laterally, and distributing the load more uniformly. The sliding blocks upon which each girder is laid, for the purpose of meeting the effects of contraction and expansion caused by changes of temperature, were not found to work well. In several cases the large ashlar stones upon which the bed plates were fixed, were drawn out of their places, before the blocks would slide. It is considered that the roller system, as originally specified, would have been a better arrangement. The impossibility of getting at all the surfaces, of the ironwork, to scrape and repaint them, is likewise a serious objection; for while there is no great amount of rain annually in Sind, there are heavy dews for months together, which cause a rapid oxidisation of unprotected wrought-iron. The large viaduct across the Chinnee Creek, of ten spans, each of 100 feet, for a double line, has not yet been erected, but the

iron work is already complete, and delivered at Kurrachee. The girders are of plate iron, of elliptic form in elevation.

The majority of the works of the Sind Railway were executed departmentally, as it is termed, or by the Company's own staff, without the intervention of a large Contractor. This mode of carrying on the works was forced upon the Company by the peculiar exigencies of the case. The merits of the rival systems have frequently been the subject of discussion, but the experience of the Author leads him to the conclusion, that for the execution of large works in India, under Government guarantee, the employment of a substantial Contractor is the best mode. The departmental system allows of an amount of Government interference in every petty detail which cannot exist under the contract system. As long as the works are pushed forward in accordance with the terms of the agreement with the Company, the Contractor is untrammelled, and he can act on his own discretion in the mode of carrying on his operations, without being involved in the interminable correspondence and delays which are inevitable under the departmental system.

APPENDIX.

BAHRUN VIADUCT.

COST OF EXCAVATING FOUNDATIONS, IN LOOSE SAND, DEPTHS AVERAGING 20 FEET.

Those parts which were let by contract, cost from 12 annas to 1 rupee 4 annas per 100 cubic feet, or per cubic yard 4·36 annas. Those done by day work, (after keeping a strict account for many months,) were found to cost:—

	A.	R.	A.
One muccadum,	at 6	0	6
Nine coolies,	at 4	2	4
	Rs.	2	10

For this sum $8\frac{1}{6}$ cubic yards were excavated, thus costing:

	A.
Per cubic yard,	5·14
About an equal number were excavated, by the two modes, therefore add as above,	4·36
	9·50

	R.	A.	P.
which, divided by 2, gives as the average cost per cubic yard,	0	4	9
Add for tools,	0	0	5
Average cost of excavation, or $9\frac{1}{4}d.$ per cubic yard,	0	5	2

COST OF CONCRETE.

	R.	A.	P.
Lime, per maund of 80 lbs.,	0	3	2
Sand, per 100 cubic feet,	0	12	0

Stone per 100 cubic feet:

	R.	A.	P.	R.	A.	P.
Quarrying,	1	0	0			
Breaking,	1	0	0			
Hauling,	2	12	0			
				4	12	0
Water per 100 cubic feet,				1	4	8

For 100 Cubic Feet of Concrete

	R.	A.	P.		R.	A.	P.	R.	A.	P.
Lime 17 cubic feet, at	0	3	2	per maund,	0	14	2			
Stone 33 „ „	4	12	0	per 100 cubic feet,	1	9	4			
Sand 50 „ „	0	12	0	„ „	0	6	0			
Water,					1	4	8			
Mixing and depositing in place,					2	12	0			
Total,					6	14	2			
Or per cubic yard,								1	14	0
Add for tools,								0	2	6
Total,								2	0	6

Or 4*s.* 0¾*d.* per cubic yard.

COST OF ASHLAR MASONRY, PER 100 CUBIC FEET.

Quarrying,	7	4	0			
Earthwork in baring quarry,	1	0	0			
Dressing,	30	0	0			
Water for men,	0	8	0			
Mistrie,	0	8	0			
Smith-work—labor,	1	3	0			
				40	7	0
Haulage,	3	0	0			
Setting,	12	0	0			
Water for mortar,	0	12	0			
Lime,	1	0	0			
Sand,	0	4	0			
Mistrie,	0	6	0			
Tools and contingencies,	4	11	0			
				22	1	0
Total, Rs.				62	8	0

Or 1*s.* 3*d.* per cubic foot.

BLOCK IN COURSE, (ARCHES,) PER 100 CUBIC FEET.

Quarrying,	6	4	0			
Dressing,	25	0	0			
Earthwork in baring quarry,	2	0	0			
Water for men,	0	11	0			
Smith-work—labor,	0	10	0			
Mistrie,	0	10	0			
				35	3	0
Haulage,	3	0	0			
Setting,	11	8	0			
Water for mortar,	0	14	0			
Sand,	0	8	0			
Lime,	1	8	0			
Mistrie,	1	0	0			
Tools, coal, templates, &c.,	4	3	0			
				22	9	0
Total, Rs.				57	12	0

Or £1 11*s*, 6*d.* per cubic yard.

COURSED RUBBLE, PER 100 CUBIC FEET.

	R.	A.	P.	R.	A.	P.
Quarrying,	6	0	3			
Earthwork in baring quarry,	1	0	0			
Dressing,	12	8	0			
Water for men,	0	6	0			
Mistrie,	0	8	0			
Smith-work—labor,	0	8	0			
				20	14	3
Haulage,	2	4	0			
Setting,	10	8	0			
Water for mortar,	0	14	0			
Lime,	1	8	0			
Sand,	0	8	0			
Mistrie,	0	4	0			
				15	14	0
Total,				Rs. 36	12	3

Or £1 0*s* 0¾*d* nearly, per cubic yard.

COMMON RUBBLE, PER 100 CUBIC FEET.

	R.	A.	P.	R.	A.	P.
Quarrying,	3	6	0			
Smith-work—labor,	0	8	0			
Water for men,	0	6	0			
				4	4	0
Haulage,	2	2	0			
Setting,	10	0	0			
Lime,	1	12	0			
Sand,	0	8	0			
Mistrie,	0	8	0			
Water for mortar,	0	14	0			
Tools and contingencies,	1	10	6			
				17	6	6
Total,				Rs. 21	10	6

Or 11*s*. 9¾*d*. per cubic yard.

CENTERING.

Deodar timber in one set of centres 1,910 cubic feet.
Iron in one set of centres 36 cwt.

Timber, 1,910 cubic feet, at Rs. 1,	1,910	0	0			
Iron, 36 cwt., at Rs. 12,	432	0	0			
Carpenters' work,	140	0	0			
Smiths' work,	120	0	0			
Nails, 112 lbs., at 3 annas,	21	0	0			
Total for one centre,	Rs. 2,623	0	0			
Cost of the 12 sets was, therefore,				31,476	0	0
Fixing and removing in 32 arches,				1,920	0	0
Total,				Rs. 33,396	0	0
The timber of these centres was cut to a scantling which made it available for sleepers on the completion of the arching, and it was valued at,				18,336	0	0

Further, the centres of the Bahrun Viaduct were made use of at the Koonee and Huroola Bridges, so that the apportionment of the total cost of centering is as follows :—

	R.	A.	P.
Bahrun Viaduct, 32 arches, ...	13,386	10	8
Huroola Bridge, 3 „	1,255	0	0
Koonee Bridge, 1 „	418	5	4
Total, ... Rs	15,060	0	0

Total Cost of the Bahrun Viaduct.

Amount paid to Messrs. Bray for work performed, up to the period of taking over the contract, ...	40,412	0	0
Amount subsequently paid in the departmental execution of the works, exclusive of the higher classes of superintendence, . . .	206,944	6	4
Amounts chargeable under the head of plant, including trollies, crabs, chains, ropes, poles, scaffolding, &c., ...	24,500	0	0
Total, ... Rs.	271,856	6	4
Or in English money, ...	£27,185	12*s*.	10*d*.

COST OF MASONRY AT KURRACHEE.

The following is a statement of the prime cost of masonry in the neighbourhood of Kurrachee, exclusive of European superintendence and working plant :—

Ashlar.	R.	A.	P.
Two good men will prepare 8 cubic feet per day for 20 annas × 12½, or for 100 cubic feet, ...	15	10	0
Two good men will set in general work 20 cubic feet per day for 20 annas, making for 100 cubic feet, ...	6	4	0
To labor, including coolies', nowgunnies', smiths', and mistrie's pay, . .	15	4	0
Cost of contractor's part, ... Rs.	37	2	0
Add for quarrying stone, exclusive of powder, &c., for 100 cubic feet, .	4	0	0
Ditto for delivery of stone, if 5 miles lead and supposing each cart to contain 7 cubic feet, at 12 annas per cart load, or for 100 cubic feet, .	10	11	5
Ditto for lime delivered on the works, ...	2	12	0
Ditto for sand, „ „ „	1	4	0
Ditto for water, „ „ „	0	12	0
Total for 100 cubic feet, ... Rs.	56	9	5

£1 10*s*. 6¾*d*. per yard,
Or about 1*s*. 4¼*d*. per cubic foot.

Block in Course.			
Two good men will prepare 12 cubic feet per day, at 10 annas per day for each man, making for 100 cubic feet, ...	10	6	8
Two good men will set in general work 20 cubic feet per day, at 10 annas eachman per day, or for 100 cubic feet, ...	6	4	0
To labor, including coolies', nowgunnies', smiths', bullocks', and mistrie's pay, ...	10	8	0
Cost of contractor's part, ... Rs.	27	2	8

	R.	A.	P.
Brought forward, ...	27	2	8
Add for stone in quarry, exclusive of powder, &c, per 100 cubic feet, .	4	0	0
Ditto for delivery of stone, if 5 miles lead, and supposing each cart to contain 7 cubic feet, at 12 annas per cart load, per 100 cubic feet, . .	10	11	5
Ditto for sand, ... per ditto, ...	1	8	0
Ditto for water, ... per ditto, ...	0	14	0
Ditto for lime delivered upon the work, . . . per ditto, ...	3	0	0
Total for 100 cubic feet, ... Rs.	47	4	1

Or £1 5*s* 6¼*d*. per yard.

Coursed Rubble.

Two good men will prepare 20 cubic feet per day, at 10 annas per day for each man, making for 100 cubic feet, ...	6	4	0
Two good men will set in general work 30 cubic feet per day, at 10 annas each man per day, making for 100 cubic feet, ...	4	2	8
To labor, including coolies', nowgunnies', smiths', bullocks', and mistries' pay, ...	10	8	0
Cost of contractor's part, ... Rs.	20	14	8
Add for stone in quarry, exclusive of powder, &c, per 100 cubic feet, .	3	8	0
Ditto for delivery of stone, if 5 miles lead, and supposing each cart to contain 7 cubic feet, at 12 annas per cart load, per 100 cubic feet, . .	10	11	5
Ditto for sand, ... per ditto, ...	1	8	0
Ditto for water, ... per ditto, ...	0	14	0
Ditto for line delivered upon the work, . . . per ditto, ...	2	12	0
Total for 100 cubic feet, ... Rs	40	4	1

Or £1 1*s*. 8¼*d*. per yard.

A Superior Class of Rubble.

Two good men will prepare and set 40 cubic feet per day, at 10 annas per day for each man, making for 100 cubic feet, ...	3	2	0
To labor, including coolies', nowgunnies', smiths', bullocks', and mistries' pay, ...	8	0	0
Cost of contractor's part, ... Rs.	11	2	0
Add for stone in quarry, exclusive of powder, &c, per 100 cubic feet, .	3	8	0
Ditto for delivery of stone, if 5 miles lead, and supposing each cart to contain 7 cubic feet, ... per 100 cubic feet, ...	10	11	5
Ditto for sand, ... per ditto, ...	1	10	0
Ditto for water, ... per ditto, ...	1	0	0
Ditto for lime delivered upon the work, per ditto, ...	3	0	0
Total for 100 cubic feet, ... Rs.	30	15	5

Or 16*s*. 8*d*. per yard.

John Brunton.

No. LXXXVII.

CUTTACK RIVER WORKS.

Report on the Mahanuddy and Katjooree River Floods and the works executed near Cuttack. By Capt. Harris, R.E., *and* Mr. Armstrong C.E. *Compiled from the Bengal Government Selections.* By Capt. F. D. Brown, *Assist. Engineer.*

The Mahanuddy river takes its rise near Bustar, in the province of Nagpore, and after passing the towns of Sumbhulpoor and Sonepore, and receiving near the latter mentioned place, the waters of the Tel Nuddy, enters the plains of Orissa Proper at Naraj.

For many miles above, and for nine below, the village of Tickreeporah, 83 miles above Naraj, the river's bed is rocky and irregular and channel narrow, floods rising to the extraordinary height of 60 feet above cold weather level. This channel then opens out to an average width of nearly two miles, a condition which it retains over a course of 46 miles above and 12 beyond Bydessur (28 miles above Naraj); it is then narrowed in its passage between the Rootrapoor and Domeparah hills, again expanded even to a greater extent than before; and lastly, contracted in width to less than half a mile, between the hills of Sydessur and Dawakote, whence, after a course of about 530 miles, it debouches upon the plains at Naraj, as above stated, where the Katjooree leaves the main channel, forming the head of a great delta, within which is situated the large city of Cuttack, about 50 miles distant from the sea.

Measured along the mid-channel, the distances from Naraj to the Mahanuddy and Katjooree sides of Cuttack (where the gauges, presently to be alluded to, were placed) are nine and six miles, respectively, the Mahanuddy

falling into the sea, after a further course of 60 miles, in the vicinity of False Point Light House. Its total length therefore may be estimated at about 600 miles.

At the time of the founding of the city of Cuttack the state of this river and its branches was very different from that which now obtains.

The Mahanuddy ("maha," great; "nuddee," river) is represented to have been ever the great "par excellence," next in succession ranked the Beropa nuddy, entitled also to the designation of a "river," and be it remarked, the only branch that was so. The Katjooree (from "khat," a log; "joor," a small nullah) is said to have been (but when, is not exactly known) an insignificant nullah, crossed by a single log of wood; and, to complete the list of the various branches of the Mahanuddy, the Khookye ("khoa," a crow; "khye," a hollow) is reported to have been a hollow in which the crows of the neighbourhood found a sufficiency of water to enable them to dip their beaks with advantage.

In February 1855, Lieutenant Short, Officiating Executive Engineer, Cuttack Circle, submitted a memorandum pointing out the yearly enlargement of the Katjooree at its head, and the proportional narrowing, by silting, of the headway of the Mahanuddy; the consequence being that, in flood, the quantity of water flowing into the Katjooree is greatly in excess of the capabilities of the channel to carry it off, thus, not only endangering the stability of the Cuttack revetment wall, on which the safety of the town depends, but also risking the great probability of the Katjooree leaving its bed and taking to the channel of the Khookye, which would inevitably flood the southern districts.

The extraordinary flood of 1855, which on the 29th July, rose to 27 35 feet above dry weather level, and by which the town of Cuttack, with its cantonment and Government offices, barely escaped entire destruction, necessitated immediate measures on the part of Government. The report of Lieutenant Harris, the Executive Engineer, immediately after this flood, thus describes Cuttack, and gives other useful data.

The Rajah Nirupa Kisseree first planted a city on the site of modern Cuttack, in A.D. 989. His reign was distinguished by the construction of a stone revetment, or embankment faced with that material. In A.D. 1174, the Rajah Aurang Bhim Deo, induced by some omen, built a magnificent palace on the site of Fort Barahittee, adjoining the town of Cuttack. The construction of the present castle of that name should,

in all probability be referred to this period, though a later date is generally assigned to it. The site of the town is low, one of the principal roads, being in parts 7 feet below the flood levels of the Mahanuddy and Katjooree, in 1855, and the town is protected from inundation by the revetment walls facing either river, connected at their ends by earthen embankments.

This revetment, constructed of large blocks of laterite and sandstone, set in mud cement, and pointed with plaster exteriorly, is raised from 17 to 36 feet above the low water line, the width at top and bottom being respectively from 3 to 4 and 5 to 8 feet. It is not known to have any foundation, other than such as it has formed for itself by settlements, either gradual, owing to the action of gravity upon the loose soil beneath it, reduced as it is, during floods to a semifluid state, or again bodily, in the form of breaches after the subsidence of the waters. It is not during the height, but after the fall of a flood, that breaches occur, owing to the difference of pressure in front and rear of the wall, caused by the fall of the flood before the backing has had time to dry.

From 12 miles below Bydessur to Naraj, the lateral limit of the Mahanuddy, though not continuously, is rigidly and clearly defined, by hills or rocks; thus the bar to any general change in the river's course between the points named is most complete.

At the head of the delta is found a sandy tract of nearly three miles in width, whence the Katjooree takes its departure. The right bank of this broad channel is comparatively low, of a light soil, offering little or no resistance to the action of the flood, whilst the left bank is generally of a higher level, or embanked, where not so, in many places; and, as in the upper portion of the river, defining permanently, by its rocky points, the limits to the lateral action of the flood. The fact should be here noticed of at least a third of a mile in breadth of the Katjooree's right bank having been carried away during the past 15 years between Naraj and Chargurreah. The soil at the latter village, for a short length and breadth, being of a very stiff clay, places a temporary restriction upon the encroachments of the river during floods.

According to the mean of â great many calculations of the discharge of the flood of the Mahanuddy made by Lieutenant Harris, it appears that on the 29th July, 1855, when the flood was at its highest, a volume of 18,00,000 cubic feet of water per second rolled into the delta, which was distributed in nearly the following proportions amongst its branches:—

Mahanuddy, 18,00,000. Velocity, 8′ per sec.	Mahanuddy, 10,30,000. Velocity, 7′ 15 per sec.	Baropa, 1,34,000.
		Mahanuddy and Pyka, 8,96,000.
	Katjooree, 7,70,000. Velocity, 7′ 32 per sec.	Katjooree, 5,05,000.
		Khookye, 2,65,000.

The Mahanuddy running the more lengthened course of nine miles from Naraj to Cuttack, passed the gauge on a level of 121·13 of the division datum, its velocity and direction of current being perfectly harmless. On the other hand, the flood of the Katjooree having a course of only six miles, direct as the crow flies, from Naraj to the revetment, reached to 127·13 on the opposite or corresponding guage; *i. e.*, 6 feet higher than the level of the Mahanuddy on the north side of the town. Its level, direction, and velocity of current, each produced a great amount of evil. tearing up the sandy bed at the toe of the revetment wall, and topping the wall itself, bursting the Kanugur bund below Cuttack, and throwing off a portion of its waters to deploy and mingle with those of the Mahanuddy in the rear attack upon the town.

State of the Embankments.—Besides the danger of the destruction of the town of Cuttack by floods, there are other evils, no less serious to the lives and property of the inhabitants of the district of Cuttack, caused by the floods, and which also have to be carefully examined before any attempt can be made towards interfering with the course of these rivers. Owing to the nature of delta rivers, the banks being on a higher level then the country beyond, when floods come down over-topping these banks, the whole district is inundated, destroying the crops, villages, and cattle of the inhabitants; the consequence is that for years the natives have been in the habit of confining the ordinary floods in their own channels by means of embankments, which, owing to their want of Engineering skill, have been very rudely laid out and constructed. Within the last 25 years, Government has taken these embankments in hand, and a report on the cause of the constantly occurring breaches was called for and submitted in August 1857, by Captain Short, Superintendent of Embankments, Lower Provinces, from which the following information is chiefly derived.

In 1804, Captain Rigby first took charge of the embankments, and repaired and strengthened them till 1845, when an order was issued prohibiting all but the repairs necessary to prevent actual breaches, while the question of abolition or retention of embankments was under discussion.

From this period to 1849, the embankments (no other orders having been issued) necessarily deteriorated and became useless. There is no doubt that, as the course of rivers changes, some embankments must become useless, whilst other new ones may be required, but this wholesale neglect of the existing bunds appears to have been deprecated by Capt. Short. Captain Beadle, Superintendent of Embankments, writes however, in June 1859, that though no doubt the bunds have deteriorated, yet with a knowledge of the fact that the great floods have an excess volume calculated at 900,000 cubic feet per second, above what the delta channels in the Pooree and Cuttack districts, embanked as they are, can contain and carry off to the sea, one can only feel it was a mercy that the embankments had not been continuously raised and strengthened up to the period of the great floods arriving. The catastrophe would only have been more disastrous, the floods would have risen higher, and the city of Cuttack must have been swept away by a flood from the Katjoree rushing into the lower level of the Mahanuddy. Practically, however, "during the last four years of great floods, a very small amount has been remitted from the revenue, and the year 1858-59 has been a year of abundant crops."

Owing to the orders of Government, prohibiting all but repairs necessary to prevent actual breaches, and of six officers having charge of the embankments during the four years from 1849-50 to 1852-53, Captain Short remarks, that they were in a state which baffles all description, the floods of 1852-53 having breached them in 1,167 localities and devastated the country; and that when he took charge of them he "found, during a careful inspection, that the head and neck of the embanking system had been destroyed, the trunk weak and insufficient, and that with corrupt and ill paid working darogahs, and with no supervising establishment, a heavy task had devolved upon him." The floods continuing each year; in 1853-54, there were 942 breaches, in 1854-55, 878 breaches. In 1855-56, the amount of Rs. 1,20,789 was expended on embankments, and accordingly in 1856-57, the number of breaches was reduced to 404. The height of the floods is increased by the direction of the wind, by spring tides, and by the Chilka or sea floods; the last rushing up the Bargovee, act as a complete barrier to the egress of even an ordinary flood, and with a flood similar to those of 1854 and 1855, the highest embankments are topped and enormous breaches occur, swamping the country.

Mr. Rayner, Officiating Executive Engineer, Pooree Embankments, in August 1857, reporting a flood on the Dyah (one of the outlets of the Katjooree), states that embankments 15 feet high were topped, and that at Neepoor, three breaches were made, one of which was 2,000 feet long. He says, "I can vouch for the very excellent manner in which this new line was completed. It was raised by layers and well consolidated throughout, it had a crest 10 feet broad with slopes 3 and 4 to 1, and was piled with strong stakes on either side; but even this was unable to withstand the combined force of a stoppage by the spring tides and a storm on the Chilka, and the effects of the floods of the Dyah and Gungird rivers.

But there are other causes at work tending to endanger the safety of such embankments wherever they exist. If the rains be not plentiful, the natives will cut through the bunds to let the water into the fields even at the risk of flooding them and ruining the country for miles around, and unless proper masonry sluices be provided, under efficient control, such a practice cannot be effectually checked. A practice is even systematised by the villagers, of inserting a hollow trunk of a tree in the embankments where they wish to obtain water, carefully concealed from the Executive Officers with earth and turfing, and the darogahs are paid to connive at the practice, while in case of discovery, some one villager, whose family is during his punishment and imprisonment supported by the rest, is voluntarily made the scape-goat. This is a common practice, and many such hidden sluices have been found by the Engineer Officer at places where it appeared to him strange that breaches were constantly occurring at the same spot. Indeed, it is not to be supposed that people so dependent upon the land for their living will stand upon any ceremony in obtaining a portion of the running stream; when the crops are being dried up for the want of water they prefer bribing the darogahs; and, rather than not get the water by cuts, they will go to jail. Unfortunately, however, for the landowners, the cut that has been opened to receive a moderate flood, is rendered an extensive breach by the sudden and unexpected increase of the volume of water, which inundates and destroys the tract of cultivation it was intended to fertilize.

It is the duration and not the height of these floods which destroys the crops. Thus of the three years, 1855-56 and 1857, though the flood of 1856 was the lowest, it was the most detrimental to the crops of the country, because of its greater duration, lasting 17 days, and thus rotting and ruining the rice plant, which is the principal crop, and quickly recovers if

only submerged for a short time. In the much higher flood of 1855, which nearly submerged the whole country, and before over-riding the embankments, caused many severe gaps in them, the revenue of Cuttack lost absolutely nothing by its occurrence, it having fallen as quickly as it rose, whereas the lengthened flood of 1856, entailed a remittance of revenue in the same district of Rs. 31,442.

Besides the great damage done by drowning the crops, large deposits of sand are left by the inundation waters, which at the high velocity in their channels is easily held in suspension, and as readily deposited as soon as the velocity is checked Thus, near the village of Hunyauk, on the left bank of the Polta, the flood of 1857 rushed through a breach 220 feet long and 20 feet deep with great velocity, and left a deposit of sand on the land which made it almost barren. There was a large tank in rear of the village, which it has entirely filled up with sand.

The height of the Cuttack floods depends much upon the state of the sea tides at the critical time, particularly in South Cuttack, where the Chilka lake, under the influence of gales from the eastward, exercises a considerable control over them. The bunds themselves contracting the waterway, tend also greatly to raise the flood level Their duration depends more on the rain falls in the upper districts or drainage areas.

It is only within a late period that the district has been yearly devastated by inundations; it appears formerly to have been doomed rather to drought, as the following list shows, which gives the remissions of revenue made in various years :—

Year.*		Amount.
1834-35	Inundation. Revenue remitted, ...	1,94,363
1835-36	Not stated, ...	3,872
1836-37	Severe drought, ...	5,42,293
1837-38	Ditto, ...	10,184
1838-39	Not stated, ...	50,791
1839-40	Ditto, ...	7,64,222
1840-41	Want of water. Revenue remitted,...	4,98,262
1841-42	Ditto, ...	
1842-43	Ditto, ...	10,858

No other Table showing the reasons for remission of revenue is given, but from a statement of remissions granted and expenditure incurred on

* The amounts remitted are taken from the Statement furnished by the Revenue Board, the cause of remittance from Report of Superintendent of Embankments, dated August, 1856.

embankments in the three districts of the Cuttack Division during the 23 years, from 1834-35 to 1856-57, the former furnished by the Board of Revenue, and the latter (only commencing in 1840) by the Embankment's Office, it appears that the

	RS.	A.	P.
Total revenue remitted was, ...	25,03,734	5	$9\frac{3}{4}$
Expended on embankments, ...	4,97,834	15	$8\frac{1}{2}$
Total loss of Government, ...	30,01,569	5	$6\frac{1}{4}$

Remedies applied.—There were thus two great questions to be determined—1, The safety of Cuttack; 2, The preservation of the delta and adjoining lands from the effects of floods.

With regard to the 2nd question, it is the opinion of most, if not all the officers who have had charge of these embankments, that (considering the natural circumstances of the district of Cuttack, the crops it chiefly produces being rice, which requires much water, but still that water should not be retained on' them too long, nor rise to too great a depth), it would be advisable that the embankments should be entirely done away with rather than that ill constructed works should remain. But no further action appears to have been taken in this direction, with a view of improving the bund system or bringing it under thorough control.

With regard to the safety of the city it is evident from the above description, that the only effectual remedy for a state of things whereby the lives of 35,000 people are annually endangered, lies in effecting an alteration of the distribution of the Mahanuddy's waters in such a manner as to increase the path of current in the Katjooree between Naraj and Cuttack, diverting it the while from the revetment, and at the same time to decrease its volume. Captain Harris accordingly recommended the construction of a Masonry Weir at Naraj across the Katjooree, by which the quantity of water flowing down that river might be restricted and forced into the Mahanuddy; and a series of Brushwood Works near the city, to divert the stream from its direct course on to the revetment. By these means the Mahanuddy bed would be improved, by a gentle scour throughout the rains, and by the discharge in a single stream working during low floods, of a greater amount of silt than could be effected by the two working together; and, consequently, a diminished tendency in the bed of the main stream to rise, thus enabling it to receive during high floods

an extra volume of water. As a result of the brushwood operations, the entire silting up of the Katjooree's channel, running under the toe of the revetment wall was anticipated, and the opening of a less objectionable channel in the centre of the stream.

For these improvements an Estimate was sent in for a Weir 4,900 feet long, averaging 13 feet high, giving front and rear slopes 2 to 1 and 1 to 1, which, at Rs. 2-8-0 per 100 cubic feet, and allowing 50 per cent., for sinkage, amounted to Rs. 1,00,000. This, however, included Rs. 6,000 for brushwood operations.

Capt. Young, Chief Engineer of Bengal, proposed to throw weirs across *both* rivers, so as to regulate the supply passing down each and hereafter to lead off the water by irrigation channels above the weir, on the plan so successfully pursued in Madras. He then proceeds to say that, "although the object of the Madras works is irrigation, yet in the case of the Cauvery, we find there was another object intimately connected with it. On contrasting the physical conditions of the two branches (viz., the Cauvery and Coleroon) Lieut.-Col. Baird Smith writes, we find 'accordingly, on the one hand, a large volume, a more rapid slope, and a more direct channel than in the other. The natural result of such a combination, is the progressive deterioration of that branch which is less favorably circumstanced, by the formation of deposits at its head, and a consequent diversion of the great body of the main stream into the superior channel.' In that case success was obtained by building directly across the mouth of the Cauvery a similar dam to that which was originally built across the mouth of the Coleroon. These two dams then, it will be understood, were across the mouths of the two rivers which they separated from each other. I believe the results of experience in this case may be safely taken as some indication of what would be the consequence, were works such as are now projected (*i. e.*, the single weir), carried out in the Mahanuddy. The surplus water which causes so much anxiety by passing down the Katjooree would, I apprehend, after a lapse of time be found flowing down the Mahanuddy, and would cause equal anxiety and equally fatal results there; and there would be no remedy for this, until, as in the case of the Cauvery, another dam was thrown across the Madanuddy at its head, for the purpose of directly regulating its waters." He further proceeds to explain "that above the Madras anicuts is a large and quiet pool, from which the water is either drawn off for irrigation or runs to waste over the weir; whereas in the

present works (Naraj spur) owing to the main channel of the Mahanuddy being left open, there will be a scouring action along the foot of the dam. Also, the dry weather volume of the Mahanuddy being thus increased, and the left bank capable of erosion, the stream will probably enlarge its bed in that direction, and finally leave the Katjooree without any dry weather stream at all; it would either do this, or it would, by the scouring action alluded to, undermine and destroy the dam, and return to the Katjooree as before, in either case baffling the efforts to control it."

Capt. Harris' proposals were eventually sanctioned, and the result of the brushwood operations may be first detailed These, as above stated, had for their object the protection of the Lalbagh revetment wall at Cuttack from the action of the Katjooree, which had several times breached it and had worked deep holes close to its base.

Brushwood Works—In 1855, Capt. Harris commenced by throwing bundles of brushwood weighted with stones into the deep hollows under the Cuttack, revetment wall, "the result of which operation," he states, "was the silting up of the hollows to a large extent, and the raising of the bed of the river at sundry points. In 1856 a brushwood spur AB was constructed in the position shown in the plate, the result of which was a two-fold one. Further silting up of the hollows under the revetment wall took place, and the line of deep channel of the river was diverted from a course dead on the revetment wall to a very favorable one, parallel to it. The spur consistsd of a double row of piles driven 3 feet apart from centre to centre, and a width of 3 feet between the rows. These piles averaged 15 feet long and 8 inches in diameter at the head. They were driven 7 feet into the sandy bed, and according as a length of two or three hundred feet was completed, the space between the rows was filled up for a height of 6 feet, with fascines of brushwood, firmly packed and trodden down. The top was then tightly bound down by coir ropes, crossed from pile to pile, and the whole was thus rendered very firm and secure. There was no attempt made to weigh down the fascines with stones, as it would have been too expensive, and the result proves that this was not required, for, when the water rose over the spur, none of the brushwood bundles showed any inclination to rise, float away, or resist being confined within the original space allotted to them.

The operations of 1857 were almost *nil*, on account of the absence of the Executive Engineer during the mutiny. In 1858 a second brushwood spur, CD, was constructed by Mr. Armstrong, C.E. It was 1,923 feet

long, and constructed similar to the one in 1856. This spur cost 5 annas per foot run; the one of 1856 cost 8 annas per foot; the difference is owing in part to the fact that the last built spur was erected during the dry weather, while that of 1856 was constructed in water. The great saving however was effected in the pile driving. The engine formerly used could only drive 24 piles per diem with 16 men; the light ringing engine used for the second spur required only 12 men, and drove on an average 50 piles. To assist the action of this spur, brushwood dams were run across the deep pools from a little above the cross section JJ, and from near the spur CD down to S, at various distances, from 100 to 200 feet apart, according to the depth of the water or the state of the revetment's foundation. These dams were formed of three or four fascines, in the centre were placed one or two stones, according to their size, and the fascines tied firmly round them with three coir ropes, one at each end and one in the middle; these bundles were about 5 feet long and 2 feet in diameter in the centre, and at the end 12 inches or so.

Naraj Spur.—In connection with these brushwood operations, in 1858 was commenced the rough stone Spur at Naraj, its objects, as before stated, being to lengthen the path of current of the Katjooree river between Naraj and Cuttack, to diminish the volume of flood in that river, and to improve the Mahanuddy's bed by a mild scour throughout the rainy season.

The following facts with regard to gauge measurements of rivers, first indicated to Capt. Harris the derangement of level in the two arms of the Mahanuddy.

Supposing a gauge A, set up in a river, with a very regular and uniform channel, the level of low supply reading (say) 6 feet on the gauge; and again at some distance down-stream another gauge (B) set up, adjusted to the fall between A and B, so that the gauge measurements of the low supply of water should be identical; and supposing the rise and fall for low floods at these two gauges had been regular for a long time, when all at once the gauge measurements at B began to be lower than those at A; all other circumstances being the same, the conclusion necessarily would be that there was a deepening of the channel and a fall of bed between A and B. Again, supposing the gauge measurements to increase at B in excess of those at A; all other circumstances being equal, the conclusion would be that the channel between A and B was being silted up.

Now gauges having been established on this principle at the common

head of both rivers, and at two opposite points in their respective channels, lower down (at Cuttack), a careful comparison of their readings enabled a judgment to be formed of the changes effected in the beds of the rivers by the action of their own streams, and by the operations employed to affect them.

The principles on which the Naraj spur was originally proposed to be constructed were these—1st, To place it judiciously in a position favorable to its own stability; 2nd, That the action should be such as, by annihilating the draught down the Katjooree, in the dry season, obstructing it very materially in low floods, and to a limited extent in high ones, would produce in the Mahanuddy a draught corresponding at all times to that existing in the Katjooree; an action in fact that would lead to the then actual conditions of the two arms of the parent river being completely reversed.

The Spur was originally commenced in 1856. As soon, however, as a few thousand feet of rough stone had been collected and placed in position, work was ordered to be suspended, and it was not till June 1858, that it can be said to have been practically put in hand. 750 running feet were completed before the floods of that year, and 675 more before the end of that year. Before the floods of 1859, the spur was raised to the height of the cold weather level, as far as the opposite bank of the Katjooree, a distance of 3,000 running feet; and two small pieces of rear apron, aggregating a length of 860 running feet, were also placed in position; they were run out to a distance of 100 feet from the centre line of the spur, and were made 4 feet thick. After the floods of 1859, the works previously done were strengthened, and the heightening of it proceeded so vigorously, that by the middle of November, the spur was carried right across the river, to above the water level, and a head of 2 feet of water was produced above the spur.

The revised estimate for the above work, at a cost of Rs. 50,000, was sanctioned in 1859. The general dimensions of the revised project were as follows:—Breadth of lip, 4 feet; front slope, 1 to 1; rear slope, 1 to 1; breadth of front apron equal to height of spur; breadth of rear apron equal to four times the height of spur; thickness of both aprons 4 feet; making a total of about 20,16,000 cubic feet, which, at Rs. 2-4 per 100 cubic feet, amounts to Rs. 49,680.

The amount of work done up to the end of 1859 was 15,88,936 cubic feet, at an average rate of Rs. 1-12-6 per 100 cubic feet; and Captain Harris stated that, he had every hope of being able to complete the work

to the section proposed, with the funds at his disposal, before the floods of 1860 set in. A small gap was to be left in the spur in order not to interfere unnecessarily with the traffic on the Katjooree.

The floods of 1859 rose—1st flood, 25th June, 13 inches; 2nd flood, 29th July, 14 inches; 3rd flood, 6th September, 8 inches, higher than the corresponding floods of 1855. That the third, and greatest flood of the year 1859, should only have risen 8 inches, whilst the lesser ones rose 13 and 14 inches above those of 1855, has been accounted for by finding, since the dry season has set in, that both the bed and water lines of the Mahanuddy have fallen 18 inches. That such change has been effected by the extra volume forced into the Mahanuddy there can be no doubt; and also that that extra volume was caused by the spur. It is expected that the spur moderating the velocity of the water passing down the Katjooree arm, will prevent that river deepening its bed near Cuttack and cause a silting action to set in at that place; the brushwood operations have already raised the bed 3 feet opposite the city; a very little more silting up is needed there, but at the head a more vigorous action is expected. The low floods will deposit sand between the spur and the point A (*see* plate,) where a sand bank has already been thrown up, and thus add to the stability of the work. They will cut away and enlarge the head of the Mahanuddy at C, thereby relieving the pressure on the spur. And a large flood will, without doubt, add to the length of the sand bank between the points A and D, and help to close the head of the Katjooree river; it will also heap up sand at D and E.

In July 1860, Captain Harris reported that, on the 20th of that month, the head of water produced by the action of the Naraj spur was 4·76 feet. The danger to the work being proportional to the head of water caused by it, its stability was considered to have undergone a most ample test, having been acted on for 27 days by various heads from the maximum to $1\frac{1}{2}$ feet. As to its practical utility, a work which can produce such heads of water cannot fail of accomplishing its object of clearing out the Mahanuddy.

[As no further Reports have been received of dangerous inundations at Cuttack, and but a cursory notice has been taken of them in the Annual Reports, it may be presumed that the works above described have been successful in their main object —the protection of the city from floods.—(Ed.)]

No. LXXXVIII.

IRON TIE-BARS FOR ROOFS.

On the proper dimensions of Iron Tie-Bars for Circular Brick Arched Roofs.

To the Editor.

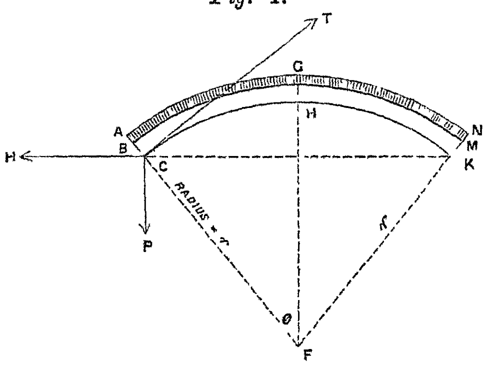
DEAR SIR,—Having had occasion to estimate and design some Vaulted Roofs of late, I send the calculations on which I based my design, as they may be useful to some of your readers of the "Professional Papers."

Yours truly,

A.

Let BCKM represent a circular brick roof, ABMN the terracing laid over the roof to make it water-tight. The weight of the terracing laid uniformly over the voussoirs will have the same effect in increasing the horizontal thrust, as would ensue if we suppose the terracing to be removed, and the specific gravity of each voussoir to be increased; so as to make the total weight of the supposed voussoirs equal to the weight of the voussoirs and terracing as actually constructed. Let BC represent any joint of the arch, θ the angle at the centre corresponding to the half

Fig. 1.



arch. The pressure T, in the direction of the tangent at C; P, the weight of the half arch; and H, the horizontal thrust or tension on the tie-bar; are evidently connected by the equations—

$$T = H \,.\, \sec\theta = P \,.\, \operatorname{cosec}\theta$$

$$\text{and } H = \text{horizontal tension} = P \,.\, \cot\theta$$

Now, there must be some point at which the expression $P \,.\, \cot\theta$ is a maximum, and if we make the tie-rods sufficiently strong to resist this maximum thrust, we shall be on the safe side.

To determine the value of θ for which $P \,.\, \cot\theta$ is a maximum,

Let $r = CF =$ radius of arch,

$z = BC =$ thickness of arch,

$w =$ weight in lbs. of one cubic foot

of the material of the arch, supposed increased in specific gravity to allow for the weight of the terracing. We then have—

$$P = \left(r + \frac{z}{2}\right)\theta \,.\, z \,.\, w \,. \text{ and}$$

$$H = P\cot\theta = \left(r + \frac{z}{2}\right)\theta \,.\, z \,.\, w \,.\, \cot\theta.$$

which expression must be a maximum; or, since r and z are constants, $u = \theta \,.\, \cot\theta =$ a maximum.

Differentiating and equating to 0,

$$\frac{du}{d\theta} = \cot\theta - \frac{\theta}{\sin^2\theta} = 0, \text{ whence } \theta = 0,$$

and the maximum horizontal thrust is at the crown of the arch.

The greatest possible thrust of the arch is therefore represented by the value of the expression $\left(r + \frac{z}{2}\right)\theta \,.\, z \,.\, w \,.\, \cot\theta$; or which is the same thing, $\left(r + \frac{z}{2}\right) z \,.\, w \,.\, \frac{\theta}{\tan\theta}$; when $\theta = 0$.

Now $\frac{\theta}{\tan\theta}$, when $\theta = 0$, is a vanishing fraction, the ultimate value of which can be found by the ordinary means; or

$$\frac{\theta}{\tan\theta} = \frac{\frac{d\,\theta}{d\,\theta}}{\frac{d\,\theta}{\cos^2\theta\, d\,\theta}} = \frac{1}{\sec^2\theta} = 1, \text{ when } \theta = 0.$$

Hence the greatest possible thrust on the tie-bar for 1 foot in width of the arch is

$$\left(r + \frac{z}{2}\right) z \,.\, w \,.\, \frac{\theta}{\tan\theta} = \frac{w}{2}\left(2\,rz + z^2\right); \text{ since } \frac{\theta}{\tan\theta} = 1.$$

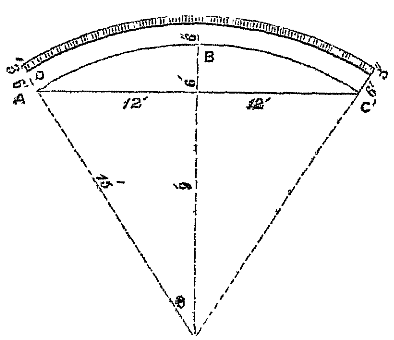
The same result may be obtained by considering that the thrust at any

point of a normally pressed ring, is represented by the product of the radius of curvature at that point, and of the intensity of the normal force per unit of length of the ring.

In this particular case, the centre line of the voussoirs may be taken as a ring, which, at the crown is acted on by a normal force whose intensity is $z \,.\, w$. The thrust, therefore, at that point in the direction of the tangent, or horizontally, is $z \,.\, w \,.\, \left(r + \frac{z}{2}\right)$ or $\frac{w}{2}\left(2\,r\,z + z^2\right)$ the same result as before; $\left(r + \frac{z}{2}\right)$ being the radius of curvature of the middle points of the voussoirs. It has also been proved that the maximum horizontal thrust in such an arch is at the crown.

Practical Example.—Let ABC represent an arched roof, 24 feet clear span and 6 feet rise. The arch is 6 inches thick, and the terracing above it 3 inches thick; the arching and terracing being of brick are supposed to weigh 120 lbs. to the cubic foot. If the terracing were removed the arch bricks would need to weigh 120 + 60, or 180 lbs., so that the weight of the whole roof should remain unaltered.

Fig. 2.



We have then got in the formula—

$$z = 6 \text{ inches} = \cdot 5 \text{ feet},\ r = 15 \text{ feet},\ w = 180 \text{ lbs.}$$

Hence substituting, Horizontal Thrust per lineal foot

$$= \frac{w}{2}.\,(2\,rz + z^2) = \frac{180}{2}\left\{2 \times 15 \times \cdot 5 + \cdot 25\right\}$$

$$= 90 \times 15{\cdot}25 = 1{,}374 \text{ lbs., or about } 1{,}400 \text{ lbs.}$$

The Tie-bars being of 1-inch round iron capable of supporting a tension of 7,854 lbs., would therefore need to be $\frac{7{,}854}{1{,}400}$ feet, or 5·61 feet apart from centre to centre.

The Horizontal Thrust as obtained by this formula may, at first sight, seem rather small; but many roofs of 40 feet span and upwards have been

constructed with tie-rods much further apart than would have been given by this formula, and have stood well for years, although the strain on the iron is no doubt greater than what is usually considered quite safe.

The formula may also be use for determining the least safe thickness of a brick or stone circular arch of given dimensions.

Referring to the first figure and calculation

$$T = \text{pressure on the joint } BC = H \,.\, \sec \theta.$$

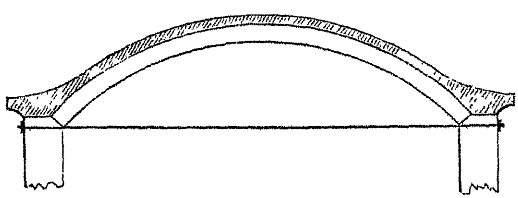
Now, in the numerical example, the greatest possible value of H has been found to be 1,400 lbs. per running foot, and $\sec \theta = \frac{15}{9} = \frac{5}{3}$.

Hence (Fig. 2), the greatest possible pressure on the joint AD, per running foot, will be $= 1400 \,.\, \frac{5}{3} = 2{,}333$ lbs., which may be supposed uniformly distributed over the surface of the joint 12×6 inches, or 72 square inches. The pressure on the joint will therefore be about 33 lbs. to the square inch; the safe co-efficient for brick being from 55 to 80 lbs. to the square inch.

In conclusion, it may be as well to remark, that the above formulæ are strictly correct, only so long as the arch and terracing above it are of uniform thickness throughout. In practice, this is almost always the case, as far as the arch itself is concerned, but the terracing is generally curved off for the sake of appearance, and is somewhat thicker towards the abutments. In most cases, however, this extra thickness over the abutments would, by its weight and consequent friction, serve to diminish the tension on the tie-rods and not to increase it.

A.

Fig. 3.



No. LXXXIX.

THE CAVOUR CANAL.

Memorandum by Lieutenant Colonel J. H. Dyas, R.E., *Chief Engineer of Irrigation Works, N. W. Provinces, No.* 70, *dated 7th September*, 1865.

The Chief Engineer of Irrigation Works, North Western Provinces, in November last, thinking that, with especial reference to the remodelling of the Ganges Canal, much valuable information and many useful hints might be obtained from the works of the Cavour Canal, then in progress in Piedmont, suggested that Government should procure a copy of the project, with plans, &c.

2.—The London Directors of the "Italian Irrigation Canal Company," with prompt courtesy, forwarded several Reports, Maps, and Photographs, and wrote to Italy for drawings of the works.

3.—The following is a list of the documents received:—

1.—General Map of the District.

2.—Bird's-eye view of the whole line of canal.

3 to 13.—Photographs of the principal works in progress, taken in November, 1864.

14.—Sketch project of 1862.

15 —Report of London Committee, dated 8th July, 1863.

16.—Engineer's report, and Memorandum by Colonel Collyer, dated 10th February, 1864.

17.—Report of the London Committee, dated 29th June, 1864.

4.—The Chief Engineer, Irrigation Works, N. W. Provinces, after

extracting from the above documents the information he considered most useful, has thought it best to abstract, and throw into a connected form the notes he had made, reducing all measures, &c., to those which are in common use in Northern India, and adding such remarks as he thought might prove useful to the officers of the Irrigation Department. He now begs to submit the result to Government.

5.—It will be understood that the above documents, on which the Memorandum is founded, having been published more for the information of the shareholders and of the general public, than for the use of professional men, give occasionally but scanty direct information on points of Engineering detail, and a good deal has therefore had to be supplied by conjecture or inference. Wherever this is the case, however, it is so stated. The drawings, which have been so kindly promised by the Directors will doubtless make all clear.

The Cavour Canal.

(With a Map.)

The design of utilizing the waters of the river Po in irrigation, was originated by Francesco Rossi, of the Vercellese, and was eventually brought into its present shape in 1853, under the auspices of the late Comte de Cavour, then Italian Minister of Finance.

The project which is now being carried out was drawn up by the Cavalière Carlo Noé, Inspecting Engineer of the Crown Canals. The plan was made public in 1854, and in 1862 the Italian Government resolved to grant to a Company, not only the construction of the new canal, but the cession by sale of all the existing canals possessed by the Crown in the Vercellese and in the Lomellina. The State has also guaranteed interest at 6 per cent. per annum, on the sum of £3,200,000, the total capital of the Company, for a period of 50 years, the term of the concession. Of this capital, £1,000,000 are in 50,000 shares of £20 each, and £2,200,000 in bonds bearing interest at 6 per cent. per annum.

Many of the shareholders are English; there are eight English Directors and a Chairman in London, as well as eight Directors and a President in Turin, one of the latter Directors also being English. Mr. James Abernethy, M.I.C.E., is associated with the Engineer in chief, Cavalière Noé, and three English Assistant Engineers are employed on the works. Colonel Collyer, late Royal (Madras) Engineers, is in the Direction.

The Marquis Luigi Tornielli has succeeded the late Marquis de Cavour as President of the Council of Administration.

The objects of the Company are—the construction of a trunk line of irrigation (the Cavour Canal) 53 miles long, with a capacity of discharge at the head of 3,885 cubic feet per second, to be carried across the main drainage of the Alps, from Chivasso on the left bank of the Po, ten miles east of Turin, to Galliate on the right bank of the Ticino, six miles north-east of Novara; the acquisition of the Crown Canals in the Ivrea and Vercellese provinces, for incorporation with the Cavour Canal in irrigating operations; the purchase of such private canals in the Novara province as may be necessary to give the Cavour Canal command of the whole country which lies south of Novara between the rivers Sesia and Ticino; the irrigation also of the plain between Casale and Valenza on the right bank of the Po; and the ultimate extension of the Cavour Canal into Upper Lombardy, passing it over the Ticino by an aqueduct, and at Barnate, $8\frac{3}{4}$ miles further on, tailing it into another canal (as yet only) projected by the Engineer Signor Tatti, from the Lago Maggiore, or more accurately, from the Ticino between Sesto Calende and Gola Secca. This canal was originally suggested by the Engineer and Senator Lombardini. It will have a course of $102\frac{1}{2}$ miles, running past Monza (nine miles north-north-east of Milan), and as far as Fernovo after crossing the river Adda. Signor Tatti considers it to be indispensable that the Naviglio Grande, the Martizana, and part of the Muzza Canal should also come into the system.

The first stone of the (head works of the) Cavour Canal was laid on the 1st June, 1863, by the Italian Crown Prince Humbert; and the contractors, Scanzi, Bernasconi, and Company, expected to be able to complete the whole of the works during the present year.

The average discharge of the river Po, at the site of the canal head, was ascertained by Lombardini to be 9,959 cubic feet per second for the years 1827-40, and the minimum discharge for the same period (in August 1828), 4,167 cubic feet per second.

The river Po, descending from the Monte Viso, in the Western Alps, runs through the plain of the upper Piedmont, which is formed of a deep alluvium of a most fertile character, and which is most admirably cultivated. The river irrigates the territory of Turin, where it receives the waters draining from the rich meadows that surround the town, as well as the soil

which finds its way into the under ground sewers of the city. It then pursues its course, and is swollen before reaching Chivasso by the junction of the rivers Dora Reparia, Sturia, Orco, and Malone.

The current of the Po, when full, becomes charged with an argillo-silicious mud of a most fertilizing character, of the excellence and abundance of which the most marked signs are exhibited in the course of the river. The waters of the lower Po are better than those of the Ticino and Adda, both as regards the physiological effects of the waters they contain, and the elements of fertility they bring down. The waters of the Po, tried contemporaneously at Turin and at Chivasso, with those of the Dora Baltea at Crescentino, of the Sesia at Vercelli, and of the Ticino at Buffalora, during the extreme months of winter, were found to be the highest in temperature; which property at once proves the superiority of these waters for the peculiar description of *marcite*, or water-meadows, the most perfect form of rural economy, and the ultimate resource of the Lombard agriculture in winter.

The *Doab* of the Po and the Ticino is already partially supplied with irrigation by the small Canals derived from the Dora Baltea, the Sesia, and the Ticino, all of which are ultimately tributaries of the Po. But the waters of the largest of these, the Dora Baltea, are cold from the perpetual snow of the vallies whence it rises, in Aosta, and carry down a baneful deposit of silico-magnesian sand. The mere exchange therefore, or the mixing, of the waters of the Cavour Canal with those of the existing canals will produce a considerable advantage by moderating the excessively cold and depressing nature of the waters of the Dora Baltea, as well as by securing the irrigation of the Novarese and of the Lomellina, now dependent on the Sesia which is but a precarious source of supply.

"If," observes Colonel Baird Smith, in 1851, "that noble canal (the Cavour Canal) is ever executed, as I trust it may be, not only to add new channels to those now existing, but to insure more abundant supplies to those lines which at present languish so much under the want of them: there will then be little left to desire for the action of the irrigation system of this region."*

* It is pleasant to see the terms of cordial appreciation is which Baird Smith is mentioned, and his work on "Italian irrigation" quoted, throughout these reports.

The channel of the Cavour Canal is revetted throughout with walls of brick-work on both sides. Its bottom width at the head is 131 feet, whence it is gradually reduced to a width of 65½ feet at the Dora Baltea, 6½ miles from the head. This width is maintained to the 39th mile, the crossing of the Roggia Busca, a small canal, where it is reduced to 41 feet, at which it remains constant as far as the Terdoppio, at the 48th mile; after passing which it is still further reduced to 31 feet, and this width is then maintained to the end.

The full supply depths of water in the canal are as follow:—From the head to the Elvo, 25 miles, 11·16 feet; from the Elvo to the Roggia Busca, 39 miles, 10·50 feet; and thence to the tail, 9·84 feet.

The corresponding changes of slope are not given, all that is said being that the average slope of the bed is 1·32 foot per mile, or 1 in 4,000; nor is the law of change of slope indicated, nor yet that of allotment of water.

It must be confessed that without this information it is difficult to thoroughly understand the details of the project, or even to make the dimensions given in different reports, and by different Engineers, agree in all points. However, it may be useful to draw a few inferences, even though it be necessary to correct them on receipt of fuller information.

If then we take 3,885 cubic feet per second as the discharge of the canal at its head, and 131 feet as the width of channel at the same place, we get 2·6574 feet per second as the mean velocity of the current, and 1 in 6,901 as the slope of the water's surface. In passing the Dora Baltea, the width of channel is reduced by one-half, the original depth being maintained, so that the velocity must be nearly doubled there, for it is not likely that much water is issued from the canal in the narrow strip, 6½ miles long, between the Po and the Dora Baltea. It is probable that the width is thus reduced in order to save expense in building the massive aqueduct and embankments, &c. The soil must be good to stand so great a velocity. From the Dora Baltea to the Sesia also, no very great quantity of water can be issued, as that tract is already well irrigated by existing Canals. The Casale neighbourhood however, on the right bank of the Po has to be provided for, and the branch canal for this purpose would probably take out about half way between the Dora Baltea and the Elvo. Thus the *great* expenditure of water must take place between the Sesia and the Ticino, or from the 36th

to the 53rd miles. It is not stated how much water is reserved for the left bank of the Ticino, but, taking the width of channel at 31 feet, its depth at 9·84 feet, and the mean velocity of the current at $2\frac{1}{2}$ feet per second, we get a discharge of 763 cubic feet per second. Or, in another way, taking the discharge at the head of the canal at 3,885 cubic feet per second, and the expenditure of water between the head and the Ticino at 3,250, a balance of 635 cubic feet per second remains for irrigation on the left bank of that river. The actual quantity may lie between these two estimates.

It will be understood that in consequence of the line of canal crossing the *Doab* of the Po and the Ticino, it was possible to choose the slope most convenient for the objects in view, and to carry it out without a single fall on the trunk line. It is probable, however, that there must be a temporary fall at the tail, into the Ticino, until the completion of the works for carrying the canal across that river, unless indeed the Langosco canal is large enough to take up the tail escape water of the Cavour Canal, and high enough to do so without a fall into it being required.

Navigation does not appear to be contemplated, as, independently of the great velocity of the current, the massive granite lintels which do duty for arches (as they would have to be in Northern India) over the openings of the regulating bridge at Chivasso, are raised above the sill not much more than is sufficient to admit of the free passage of the full supply of water; there is but little head-way under the arches of road bridges, &c., and there are no tow-paths under them; and there are four siphons on the line.

Navigation is not even mentioned in the reports. The able Engineer who designed the Cavour Canal no doubt had good reasons for confining himself to irrigation. The omission of all special provision for navigation must certainly cheapen the cost of the canal as one of irrigation, and shorten the time required for its completion. The Turin and Milan Railway also runs nearly parallel with and close to the canal, which is crossed by it at the 23rd mile. Still looking to the ultimate extension of the Cavour Canal across the Ticino, and its probable future connection with the Naviglio Grande and other navigable canals, it must be regretted that the requisites for navigation could not have been combined with those for irrigation, in this work.

There are nineteen canal *Chokees* along the line, at intervals of about 3 miles each.

The head-works consist of an open weir running diagonally across the river, connected with, and in continuation of, a solid masonry spur which has been pushed out (and up-stream) from the left bank (canal side) of the river. An escape, or set of scouring sluices, is provided between the spur and the mouth of the canal; and a second escape, of 9 openings, is built close up to the regulating bridge, which is thrown back some 1,000 feet or so from the mouth of the canal and from the river's bank. Over the regulating bridge, which has 16 openings, and the escape connected with it, are built houses for the protection of the regulating gear, and of the establishment for working it. The annexed perspective view will give a general idea of the whole arrangement. All the parts of the head-works which are exposed to the action of water are built of, or faced with, large blocks of cut stone obtained from quarries opened out immediately opposite on the right bank of the Po.

In addition to the two escapes already mentioned, a third called the escape of the Poasso, with a channel 4,100 feet long, also leading into the Po, occurs at 2½ miles from the canal head. These escapes have their channels revetted with brick-work. A fourth escape occurs at 6½ miles, 200 feet long, into the Dora Baltea; a fifth, at the 25th mile, 4,400 feet long, into the torrent Elvo; a sixth, at the 29th mile, 200 feet long, into the torrent Cervo; a seventh, at the 36th mile, 4,400 feet long, into the river Sesia; an eighth, at 45½ miles, 3,900 feet long, into the torrent Agogna; a ninth, at the 48th mile, 2,800 feet long, into the torrent Terdoppio; and the tenth, at the 53rd mile, is the tail escape into the river Ticino.

These escapes were originally drainage cuts, or the down-stream portions of diversion, or relieving channels, opened for the purpose of turning the stream round the works, or of getting rid of the water in the foundations while the works were in progress They are now turned into permanent works with sluice-gates at their heads. It is probably intended to make use of some of these escape-heads as irrigation outlets, or heads of branch canals; for no mention is made in the reports of any such works, and an escape every five miles on the average would appear to be more than could be required for purposes of regulation.

It will now be seen what an expensive part of the undertaking the crossing of the whole drainage of the country must have been. But it

was in fact the only way of bringing the water to the land which it was destined to irrigate.

It will be observed also that no attempt appears to have been made to divert any of the smaller drainages into larger ones, an expedient which has been found useful in India There were doubtless good reasons for not attempting it. There is one small torrent, the Dondoglio, near the Marchiazza, $34\frac{1}{3}$ mile, of which no mention is made in the reports; possibly it may have been diverted into the Marchiazza.

Two rivers, the Dora Baltea, deriving its supply from Mont Blanc and the great St. Bernard, and the Sesia, have been crossed, in addition to six torrents, the Elvo, the Cervo, the Roasenda, the Marchiazza, the Agogna, and the Terdoppio.

Of these, the Dora Baltea is crossed by an aqueduct 635 feet long, consisting of nine arches of $52\frac{1}{2}$ feet span each, on $9\frac{1}{2}$ feet piers, and abutments $43\frac{1}{4}$ feet each. The length of embankment formed across the valley of this river is 7,353 feet additional.

The Sesia is carried across the canal by a superpassage 820 feet wide, on five arched openings, through which, as siphons, the canal flows.

The Elvo, the Agogna, and the Terdoppio, also cross the canal by superpassages, which are siphons as regards the canal. That for the Elvo, is 656 feet wide, on five arches; those for the other two torrents are on three arches each, and have a width of 161 feet and 142 feet, respectively.

The canal is carried over the Cervo by an aqueduct 511 feet long, on five arches. The valley embankments are 2,428 feet long additional.

The Roasenda, 33rd mile, and the Marchiazza, 34th mile, flow under the canal through culverts of three vents each, the length of the former work being 178 feet, with valley embankments 2,428 feet long, and that of the latter, 102 feet, with embankments 3,260 feet long.

All these works are built in much the same style, plain and solid, of excellent brick-work, the cut-waters faced and capped with cut stone, and occasionally a string-course of the same material.

There are also numerous minor works, as road bridges, and the aqueducts, culverts, and siphons required for the passage of the waters of the several small canals whose courses have been intersected by the Cavour Canal. These were originally set down at 500 in number, but the contractors have been able, by arranging with the land-holders, to reduce the number to 326.

Of these small canals, the Ivrea, receiving 700 cubic feet per second, and measuring with its accessories, 92½ miles in length; the Cigliano, 650 cubic feet per second, and 102½ miles long; and the Rotto, 600 cubic feet per second, and 84½ miles long; Crown Canals, drawn from the river Dora Baltea on its left bank, have been made over to the company; as also the Sartirana, 220 cubic feet per second, and 100½ miles long, drawn from the left bank of the river Sesia.

The Busca, 65 cubic feet per second, 39¼ miles long, and the Rizzo-Biraga, 90 cubic feet per second, 88¼ miles long, have been purchased from the former owners, and negotiations are in train for the purchase of the Mora, 130 cubic feet per second, 32½ miles long, and of the Langosco, from the right bank of the Ticino, 249 cubic feet per second, and 27 miles long.

The aggregate discharge of the Crown Canals made over to the Company is 2,170 cubic feet per second and their united length 380 miles. The discharge of the private canal streams is 534 cubic feet per second, and their length 188 miles. The total discharge therefore of existing canals which are, or are about to become, the property of the Company is 2,704 cubic feet per second, and the total length 568 miles.

On the Crown Canals ceded to the Company are 17 mills, yielding an annual revenue of £2,400. Collective H. P., 650.

It does not appear to be the intention of the Company to construct at their own expense the subsidiary canals from the Cavour Canal; but the Council of Administration have entered into an arrangement with first class capitalists for the establishment of an Agricultural Bank, by the aid of which the landholders may be supplied with the capital required for the construction of subsidiary water-courses, and for levelling their lands.

The total estimated cost of the Cavour Canal is £1,774,995;* in addition to which £361,005 have been appropriated to the payment of interest from the time of the first formation of the Company until the completion of the works, thus allowing £2,136,000 for the new canal; the Crown Canals have cost £812,000; and a sum of £252,000 has been set aside for the purchase of private canals, &c., making in all £3,200,000, the capital of the company.

The annual current expenditure is thus estimated—

* It is not stated whether this sum includes compensation for land occupied.

Interest, @ 6 per cent. on £2,200,000, Bonds, ...		£132,000
Expenses (establishment, maintenance, &c.,) ...		16,000
Grand Total current expenditure, ...		£148,000

The returns are calculated as follows:—

Water-rate on 296,544 acres, @ about 16*s.* $2\frac{1}{4}$*d.*, per acre, ...		£240,000
Water-rate on 18,534 acres *(marcite)*, @ about 6*s.* $5\frac{3}{4}$*d.*. per acre, ...		6,000
Total 315,078 acres, and water-rate, ...		£246,000
Mill-rent, ...		6,000
Total revenue from new canal, ...		£252,000
Present revenue of crown canals, ...	£32,480	
Additional revenue from same by reason of increased supply, ...	4,000	36,480
Grand Total returns, ...		£288,480

Thus, the net profit is estimated to be £140,480 per annum, which will give a 14 per cent. dividend on the share capital of £1,000,000.

From the foregoing, the following statistical information may be deduced.

No.	Detail.	£	*s.*	*d.*	R.	A.	P.
					(Nearly.)		
1	Estimated cost, of construction only, of new trunk canal, excluding cost of distributing channels, and without navigation, per mile, $\frac{1}{53}$ (£1,774,995), ...	33,491	8	4	3,34,914	0	0
2	Estimated cost of do. do. do per cubic foot per second of discharge, $\frac{1}{3885}$ (£1,774,995), ...	456	17	8	4,569	0	0
3	Estimated cost of establishment, maintenance, and repairs, per annum, per mile of length, $\frac{1}{53}$ (£16,000), ...	301	17	9	3,019	0	0
4	Estimated cost of do. do. do. per cubic foot per second, $\frac{1}{3885}$ (£16,000)	4	2	4	41	0	0
5	Average allotted expenditure of water, per mile of trunk canal, $\frac{1}{53}$ (3,250), ... (£246,000 : £4,000 :: 315,078 Acres, : 5,123 Acres, and 315,078 + 5,123 = 320,201 acres, the total area irrigated, including additional by Crown Canals), ...	61·42 cubic feet per second.					
6	Estimated area irrigated by Cavour Canal, per cubic foot per second, $\frac{320,201}{3250}$ ...	98·52 acres.					
7	Proposed average (deduced) water-rate, per cubic foot per second, £$\frac{250,000}{3,250}$ ...	76	18	5	769	0	0

No	Detail.	£	s.	d	R	A.	P.
8	Proposed ordinary water-rates, per acre irrigated, ...	0	16	2	8	1	6
9	Proposed water-rate for *marcite*, per acre irrigated, ...	0	6	6	3	3	7
10	Actual average water-rate on Crown canals, per cubic foot per second (1,300 Fr. per module), ...	25	7	6	253	12	0
11	Actual lowest ordinary water-rate, per acre irrigated, ...	0	14	7	7	4	7
12	Actual ordinary water-rate on private canals, per acre irrigated, ...	1	1	0	10	8	0
13	Actual average annual rent paid on Crown canals for water-power, per H. P., $\frac{1}{650}$ (£2,400), ...	3	13	10	36	14	8
14	Paid by Company for Crown canals, per cubic foot per second $\frac{1}{2170}$ (£812,000), ..	374	3	1	3,742	0	0
15	Paid by Company for Crown canals, per mile, $\frac{1}{380}$ (£812,000), ...	2,136	13	6	21,367	0	0

From which, we may say roughly, that, as compared with canals in Northern India, twice as much water must be taken into the Cavour Canal in order to enable it to irrigate during the year an equal area of land; and that the farmer will have to pay three times as much for that irrigation; or if he takes water by bulk, that he will pay half as much more, for the same quantity of water, than the Indian cultivator. That is, assuming for the Indian rates those now in use (since 1st May 1865) on the Ganges and the Eastern Jumna Canals, viz.:—

Class of Crop.	Nature of Crop.	Per Acre Irrigated. By natural flow of water (Tor.)			Per Acre Irrigated. When raised by machinery (Dâl.)			Per
		Rs	A.	P.	Rs.	A.	P.	
I.	Sugar-cane, Gardens, and all lands taking a supply throughout the year,	5	0	0	3	5	4	Year.
II.	Rice, Tobacco, Opium, Vegetables, and Singharas, ...	3	0	0	2	0	0	Crop.
III.	All *Rubbee* crops, Indigo, and Cotton,	2	4	0	1	8	0	”
IV.	All *Khureef* crops, not specified above,	1	10	0	1	0	0	”

Each cubic foot of water per second which enters those canals may be said to irrigate on the average 200 acres of land during the year. In 1860-61, this area was 296 acres for the supply of the Eastern Jumna

Canal. The Ganges Canal has not yet reached so high a standard, but its average is steadily increasing; for 1863-64 it was 110 acres, and for 1864-65, 141 acres.

The average proportion of each kind and class of irrigation in every 200 acres may be approximated to as follows:—

Class.	Area irrigated (in acres.)		
	Tor.	Dâl.	Total.
I.	22 96	5 04	28
II.	29 52	6·48	36
III.	78·72	17·28	96
IV.	32·80	7 20	40
Total acres, ...	164 00	36·00	200

By combining the information given in the foregoing Tables, we get the following:—

Class.	Tor or Dâl.	Acres irrigated of each kind and class.	Rate per acre irrigated			Amount of water-rate.								
						Tor.			Dâl.			Total.		
			R.	A.	P	R.	A.	P	R.	A	P.	R.	A	P.
I.	Tor,...	22 96	5	0	0	114	12	10	...	...	...	131	9	8
	Dâl,..	5·04	3	5	4	...	...	...	16	12	10			
II.	Tor,...	29 52	3	0	0	88	9	0	...	...	...	101	2	0
	Dâl....	6 48	2	0	0	...	...	...	12	9	0			
III.	Tor,...	78·72	2	4	0	177	1	11	...	...	...	203	0	8
	Dâl,..	17·28	1	8	0	...	...	...	25	14	9			
IV.	Tor,...	32·80	1	10	8	54	10	8	...	...	...	61	13	10
	Dâl,..	7·20	1	0	0	...	...	...	7	3	2			
Total, ...	Tor,...	164·00	2	10	5	435	2	5	...	...	...	497	10	2
	Dâl,...	36·00	1	11	9	...	...	...	62	7	9			

Average rate for the 200 acres, Rs. 2-7-10 per acre. Value of 1 cubic foot of water per second for one year, about Rs. 500.

The present average (sole) rate for *Tor* irrigation in the Punjab is Rs. 2-6-8 per acre, and for *Dâl* Rs. 1-3-4.

The present rate of the Madras Irrigation Company, is Rs. 4 per acre.

The reason why in Italy, a canal must carry twice as much water as in India, in order to irrigate during the year an equal area of land, is not that the Italian farmer does not economize water as carefully as the Indian farmer, but that the sole kind of irrigation practised in Italy during the winter months is *marcite*, or water-meadow, which is of limited extent, and which, though requiring a large expenditure of water, (a thin sheet of water has to be kept constantly flowing over it,) pays but little, the rate for it on the Cavour Canal being only two-fifths of the ordinary rate. On the other hand, the area irrigated by one cubic foot of water per second in Northern India in winter (the *Rubbee* crop) is generally twice the area irrigated by the same quantity of water in summer (the *Khureef* crop.) The actual extent of *Rubbee* irrigation on the Eastern Jumna Canal amounts to 60 per cent. of the total area irrigated during the year, and on the Baree Doab Canal in the Punjab, to 56 per cent. of the same, taking in each case an average of four years.

From Italian provincial statistics it appears that the relative value, for sale or lease, of irrigated and of unirrigated land, is as 3 to 1. Mr. Abernethy adds that, "from what he has seen at the farm of the Marquis di Cavour at Leri, and in that neighbourhood, as compared with the unirrigated lands lying between Novara and the Ticino, he would be inclined to place it at a much more higher rate." Count Cavour, in 1857, stated that, "in the plains of Piedmont from Coni to the Ticino, land was letting at 32*s*. an acre, which is more than the average rent of land in Great Britain."

There appears then to be good ground for hope that the Cavour Canal will prove an exception to the general rule in Northern Italy, as stated by Colonel Baird Smith, that "Canals of irrigation, however they may benefit agriculture, are not generally successful as purely financial speculations."

No. XC.

NOTES ON ROAD METALLING.

By Lieut.-Col. Cowper, R.E.

There are numerous professional works on Roads and Road-making in all its branches, which have been published at various times in England, and which afford extremely valuable information to those engaged on such duties in India: some of these have been arranged and adapted to meet the requirements of this country, but the chief point on which the English and the Indian practice differs almost *in toto*, has been overlooked, and there exists at present no printed record or elementary work of reference which can serve as a guide to the scientific treatment of the heterogeneous materials that form the surface of our Indian roads, and which differ so greatly from those in use in England, as to render necessary a new system of treatment. As a consequence, there are numerous differences of opinion on the subject; one Executive Engineer reverses the system pursued by his predecessor, almost all proceed empirically without any fixed rules, and thence results a diversity of practice of which much must be wrong, and cause a considerable loss of money.

It is intended therefore in the few following remarks to attempt to reduce to rule the preparation and consolidation of the road materials generally in use, and more particularly those in Western India.

In the Bombay Presidency, the chief material used in Road-making is *Moorum;* as it is generally obtained close at hand at small cost, and affords the best sort of materials with which to commence a new road.

The rate at which moorum is procured in the province of Malwa, is on the average about Rs. $2\frac{3}{4}$ per 100 cubic feet for a lead of one mile, this expense being divided among the sub-heads as follows:—

		RS.	A.	P.		RS.	A.	P.
Excavating,	... ...	0	12	0	Stacking,...	0	2	0
Carrying 1 mile,...	...	1	8	0	Spreading and consolidating,...	0	6	0
" 2 " ...	...	3	0	0				
" 3 " ...	...	4	8	0	Rolling, Rs. 30 per mile.			

In using the term moorum, however, we generally include almost all descriptions of sub-soils which are suited for the surface of a road, by being at all harder than the common earth. The surface of what is usually called a moorumed road may contain in it different portions of sand, laterite, broken bricks, kunkur, yellow earth, or any hard strata, which may be met with below the surface.

The real moorum is probably rock in course of disintegration. It is met with at a depth of 2 or 3 feet in regular strata, and is nearly homogeneous in the same locality. It varies, however, in different localities at almost every mile, both with respect to its hardness and durability, as well as the size of the pieces into which it breaks. It is got with the pickaxe, and the very hardest moorum therefore that we can obtain must fall considerably short of metal. The usual form in which this material breaks is into flakes or clinkers, with sharp well defined edges; this sort is a favorable description for binding under pressure and moisture. There is another very good description of moorum which comes out in small blocks or nodules, nearly the size of a man's fist; this kind is very difficult to bind, but when once well consolidated, it makes a strong and good roadway. A third description of moorum, differing from either of the above is of a gravelly nature. It breaks up into small pieces, and forms a very smooth pleasant road in the fair season, well adapted for carrying light traffic, and does for cantonment roads. It is, however, not sufficiently strong to stand heavy traffic well, and in the rains it is not much better than an earthern road.

In some places a very inferior description of moorum, which is but little better than indurated clay, is alone procurable. It comes out in large blocks, but is so soft that it crushes under the rollers.

There is hardly any limit consequently to the size of the pieces of such moorum which may be brought on to the road.

Good moorum may generally be known at once by its gray color. It has a blueish metal-like fracture. Red moorum on the contrary is almost invariably bad.

All quarried moorum has a kind of skin or outer crust which is softer

than the interior. The binding and consolidation is somewhat assisted by this, as the pieces yield and are forced together under the rollers, but during the rains these skins becomes mud, and tend to break up the road.

In most moorum pits are found nodules or blocks of hard stone, called "tols," bedded in the strata; these make good second-class metal when broken up, but owing to the expense of so doing, it is usual to throw them into spoil banks at the pits, or use them with jungle stones to form rubble stone bottomings for the roads. By the use of these rubble stone bottoms, the surface material is separated from the sub-soil below, and we are enabled to use up all our moorum, none being pressed into the sub-soil and lost. Care, however, must be taken that the cart-wheels are never allowed to reach this bottoming, otherwise it will be broken up and forced to the surface. This is more especially necessary when the road is in a green state just after the rains; when the traffic recommences, the ruts should then be constantly raked in and generally towards the centre, to preserve the section.

From what has been above stated, we are unable to fix any limit to the size of the pieces of moorum which can be brought on the road, but must be guided by our experience at the different pits, as to the largest pieces which can be expected to bind. The softer the material is, the larger should they be as a rule, in order to give a cross section of sufficient strength to resist fracture by the cart-wheels. The same principle must be observed in forming the section of the road, the rise in the centre being greater as the material is softer.

When the moorum is procured in large pieces it will often happen that owing to a deficiency of rain or from the rolling not having been attended to, that the roadway has not bound or consolidated properly; and whenever this is the case, it should be top-dressed, with yellow earth, fine moorum, or sand, about 1 inch in thickness, and rolled; and the result will be that these portions will be well passable during the fair season. More than one inch of top-dressing would make the road heavy and muddy in wet weather, and less than this would not effect the object of binding the large moorum. Yellow earth is far preferable for this purpose to sand, as this latter hardly acts as a binder; but the former sinks down between the pieces of moorum, and consolidates them by forming into cakes in the interstices. When yellow earth cannot be procured, the next best material as a binder is fine or soft moorum. This treatment of a road surface is not to be recom-

mended as a general rule, as every heavy shower of rain disturbs the top-dressing, which may have to be renewed, but it is an expedient by means of which, a rough and inconvenient piece of road may be rendered good for the traffic during the dry season at a trifling expense.

Whenever very weak material is employed, such as sand, for the road surface, the stronger should the substratum be, as rubble stone bottoming with a layer of block moorum in large pieces. Broken brick as a material for the road should be sparingly used, being very weak, and should be brought on in a thin layer, so as to be worked up by the end of the cold weather, as it is a disagreeable material when not moist. It should be put on at the commencement of the heavy rains, and will be found when kept moist to make a somewhat tough roadway.

Such is a brief description of material with which roads are generally commenced in the Bombay Presidency. The chief fault of moorum is the facility with which it imbibes moisture. When thoroughly impregnated with it, the very best and hardest moorum will not stand traffic well, and in the rains it forms a viscous mud, and one cart at that time uses up as much material as four would in the fair season. With a few days of fine weather, the road recovers itself more rapidly than any other similar material. As a rule, therefore, in all localities where the rains are heavy, we shall have great difficulty in finding good moorum.

We are led to perceive by these facts that only the best description of moorum should be brought on in the rains, and that expense may be saved if considered advisable by using an inferior moorum for the fair weather repairs. One method of effecting this would be to screen the moorum on to the road, through a screen with meshes about $\frac{3}{4}$-inch in size, and stack these siftings, which would still have some strength in them, for the fair season repairs.

Whenever our funds will allow, the moorum is spread in a layer of 12 inches, with a rubble stone bottoming over the sub-soil, and forms a roadway perfectly capable of accommodating the traffic for the first few years. As the traffic increases, the road crust or surface loses its spongy and porous nature and becomes more tough and consolidated with each succeeding year; but we also become aware, as our road gets into use, of a great difference in strength in the several portions of the line, owing to the varying character of the moorum. Our attention must now be turned to the elimination of all such weak and bad portions of the line. New

moorum pits must be searched for, and failing their discovery, the lead from the good pits must be extended from either side of these places, so as to shut them out, and bring the strength of the line up to nearly an uniform level throughout. We also become aware, from the complaints of the cartmen, of numerous obstacles along the line, such as muddy nullahs, &c., which stop all travelling in the rains, and cause great delay in the fair season. After our outlay on the moorumed roadway, the next most productive expenditure is to carry the roadway over these obstacles by means of drains, culverts, and bridges. In the early history of a road we must submit to the evil of having our new works at a great distance apart from each other, in order to render the outlay on new works as productive as possible, and to raise the strength of the line *pari passu* with the requirements of the traffic. If an attempt be made to concentrate the establishment and outlay on any one part of a road in the first few years, the result will be that such portion will be as much too good for the traffic as the remainder will be too bad and weak. Sound economy, therefore, dictates that the worst portions of the line should be improved one after another, in the order of the obstruction they cause.

After some years of outlay on improvement of new works, we find ourselves in possession of a road excellent in all respects for the fair weather traffic, well drained and bridged throughout (with the exception of those streams which are of some considerable magnitude), but incapable from the nature of its surface, of withstanding much traffic during the monsoon; the facilities that the road has given to transport having had its usual effect, of increasing traffic and cutting up the road surface.

To remedy the defect of the weak surface, we might proceed in the manner recommended by standard authorities on the subject, and provide a stone pavement laid by hand on the present moorum surface, with 6 inches of metal over this pavement. This process is however so expensive that no one recommends its adoption, but the expedient of metalling at this stage of our road, either with or without a rubble stone bottoming, is well worth consideration.

In the Province of Malwa, the only metal procurable is made from what is called globular trap, which has the peculiarity, that however sharp the angles of the pieces of metal may be when first broken up, they invariably disintegrate into rounded masses under friction and use, and do not

bind properly except for a limited time when first spread during the monsoon. In the hot weather, this metal becomes an unconsolidated mass of rounded stones, which cannot act as a road unless by the adoption of the very expensive methods of watering and rolling. It therefore becomes a desideratum to discover whether some more efficacious and less expensive method cannot be devised to accommodate the traffic during the wet season. In many places where the moorum spread has been of a superior quality, and the crust of the road is sufficiently strong to carry with safety a thin coating of metal, it would be advisable to substitute broken stone for moorum, in the annual repairs, as at the same expenditure, stone is more durable than moorum. A strip of metal, 12 feet broad by about 2 inches deep, laid in the centre of the roadway during the monsoon, would find a bed for itself on the moorum surface. This would give about 2 cubic feet of metal to the running foot of road, instead of 4½ cubic feet of moorum, that would be required for repairing the roadway, 18 feet wide and 3 inches deep with this latter. But as 2 cubic feet of metal are fully equal in wear to 5 cubic feet of moorum, there is a saving in using stone, besides providing a road properly passable during the rains. The cubic foot of second-class metal would cost Rs. 6, and an outlay of Rs. 12 on metal would give results equal to Rs. 15 on moorum of the average quality.

The peculiarity of slow-moving traffic, more especially in this country in following on the same tracks, is one of which advantage might be taken to form a perfectly hard roadway for the wheels of the carts in the manner detailed below, which would be available throughout the year, equally in the rains as in the fair season. By laying down stone tracks at a distance apart from centre to centre equal to the average guage of the carts using the road, we should obtain a nearly perfect roadway at about one half the expense of metalling. This system has been tried in many places in England, and has been invariably very successful wherever the heavy nature of the traffic demands its adoption.

The following comparative statement shows the expense of these stone tracks and that of metalling, the rates being those prevailing in the province of Malwa :—

		RS.
Original cost per mile, ..	Metalling, ...	10,939
	Stone tracks, ...	4,905
	Saving by stone tracks, per mile, Rs. ..	6,034

Annual maintenance per mile, ..	Metalling, $1\frac{1}{2}$ inches, rolling, and watering ..	2,935
	Stone tracks, 3 inches, moorum, ..	970
	Annual saving by stone tracks per mile, Rs.	1,965

It is a fact well ascertained in practice, and supported by the experience of the best authorities, that the draught upon well laid stone tramways is less than one-quarter of what it is on a gravel road, and the proportion is probably still less with reference to a moorumed road. This would make the productive draught upon these tracks but little less than on an iron tramway, if we take into consideration the greater dead weight of the rolling stock in use on that description of road, and the difficulty of providing full loads for each van. The lowest estimate that has ever been made for a single line of iron tramway, is Rs. 20,000 per mile, and however great the facilities that would be given by the system to transports, they must be attended with a double break of bulk and consequent delay, &c., of goods. This, it is evident must deter a large amount of long distance goods, and nearly all the short distance traffic, from coming into the tramway at all.

Stone tracks might be advantageously laid along-side the present lines of road and act as feeders to the railway, at a fraction of the cost of the proposed light railway or iron tramway, and without their risk and trouble. They can be used for all descriptions of traffic for all distances without charge; there is no break of bulk, and they would develope the productive power of districts by freeing labor and keeping down the price of carriage, in a manner similar to that effected by railways.

On most lines of road, steep places, called ghauts, are met with, and as these have generally been constructed many years ago, it will be found that they are too steep in many parts for cart traffic. They have been laid out and drained at considerable expense, and could not now be altered, except at a very heavy outlay. We are enabled, however, to attain the same result, by providing stone tracks for the ascending traffic, at about a tithe of the outlay, as if the ghaut had been entirely reconstructed at a proper slope, as the draught on an ascent of 1 in 13 with these, is as light as 1 in 30 on an ordinary road. Stone tracks on even the steepest of these ghauts would facilitate the traffic as much as if the ghaut had been re-made at an incline if 1 in 30.

One mile of these tracks has been sanctioned as an experiment on the Bombay and Agra road, by the Supreme Government of India, in this

year's budget. About half a mile will be laid in the plains, and an equal length on a ghaut incline, and the result is to be reported on after a twelve months' trial. The following is the specification to which they are to be constructed

"The tracks will be excavated in black soil, and the stones used in their construction to be invariably of the best quality, fine and close grained. The size of the track stones to be 18 inches broad by 9 inches in depth, and not less than 1 foot in length each; to be bedded in well rammed moorum and stone chips, so as to prevent the stones from sinking. The foundation will be 1 foot deep and 6 inches on sides. The tracks will be flush with the general level of the road; their junction will be supported by a boulder or large stone, in length not less than that of the joint itself, and containing about $\frac{1}{2}$ cubic foot each. The top or exposed faces of the stones to be scored across with a pick to give a hold to the animals' feet. Each stone to be closely jointed to the next, by chisel dressing the end face. Amount of estimate, Rs. 4,905 for one mile."

It would be an additional precaution if the ends of the track stones were joggled together and laid in lime mortar, and it may perhaps be found necessary to do so. A plan and section of these tracks is given. They will be used by the traffic in both directions in a similar manner to the plank roads in Canada. The moorumed surface of the roadway would only be used as a "turn-out," as it is called when two carts meet. The rule of the road is very simple, and can be easily complied with by the cartmen. All non laden carts would "turn-out" for those laden; and when two carts meet, whether both were laden or were unladen, the traffic passing north would "turn-out" for that moving south, as the latter has usually the heavier loads. The traffic on the Bombay and Agra road consists for the most part of strings of carts, laden with cotton, opium, piece goods, Europe stores, &c., varying in number from 10 to 30, so that in a day's march the "turn-out" would probably only be used two or three times by any particular cart, and then only for a couple of hundred yards each time. One line of tracks would therefore accommodate any conceivable amount of traffic.

But, whatever may be the material used for the surface of the roadway, whether metal or moorum, it is necessary to bring it into a state properly passable for wheeled vehicles. This is effected by means of Rollers, by which the road surface is compressed, when saturated with moisture, into a smooth and compact stratum or pavement, by which the draught is greatly

assisted, and the material is worn more equably and lasts much longer than if used in an unconsolidated state. Rolling operations, as usually conducted, are expensive and troublesome, and in most cases are not so efficacious as they should be. They ought to be so conducted that when the road is once consolidated, it should remain so throughout the year, and the constant top-dressing, watering, and rolling, which goes on in the fair season under the present system, would be avoided. With the globular trap more especially, its nature is such that the only chance of forming a proper road surface with it, is to crush it down into a pavement, and thereby prevent the pieces from separating and woiking up to the surface; a very few rollings with rollers of the proper weight would be of more effect than any number with light rollers, and a great saving would be effected in labor, bullock power, and expense, by the adoption of rollers of great weight.

The rollers usually employed on moorum roads are made of stone, such as hard trap; they are in length about 4 feet, and 2 feet diameter, weighing say 1 ton each, or 47 lbs. to the inch of bearing surface. To ascertain whether the effect of these rollers is sufficient to give us a surface hard enough to carry the traffic without injury, we must compare the compression exercised by them with that of the wheels of a laden cart, which carry in all probability the greatest weight per inch of bearing surface of any traffic using a road. Our rolling operations will evidently be of little efficacy unless they provide a stratum sufficiently tough to resist the action of the cart-wheels, or in other words, the weight of the rollers should be, inch for inch of bearing surface, at least equal to that on the cart-wheels. We may assume that each laden cart has a total weight of at least half a ton, including the cart itself; this gives 5 cwts. on each wheel, and taking the tire at 2 inches broad, a pressure is produced of 280 lbs. per bearing inch. This is six times the pressure of our stone rollers, and leads to the belief that there is little efficacy in rolling with such light weights. It is evident that if it be possible to procure rollers with a bearing weight of 280 lbs. per inch or upwards, our labors would be much lightened. These views are confirmed by experience, as we find that with light stone rollers, the upper crust or surface is only made smooth, and below this is material in an unconsolidated state; the roadway being consequently soon cut through and broken up by the traffic. With metal, these rollers are entirely useless; wherever they are now in use, they should be got rid of as soon as possible and others substituted,

which permit of being weighted up with stone boxes and in other ways.

Before however proceeding to describe the superior kinds of rollers, it will be as well to show what can be done with the present stone rollers, so as to make them in some degree efficacious, at least for the consolidation of moorum and similar materials, it being always borne in mind that as near an approach as possible should be made with these machines to the weight on a cart-wheel. Instead of being made cylindrical, they should be either barrel-shaped or bevelled. The effect of this shape is that the bearing surface is reduced to about one-third of its former extent and the weight per inch is trebled, being now 141 lbs., or half that on a cart-wheel. These rollers can be made at the same price as the usual cylindrical ones, and are easier to turn and lighter in draught than these latter. They should more especially be made of the hardest stone procurable. There is one point about the barrel-shaped roller which appears to give it an advantage over all other shapes. It is evident that with each successive rolling as the road becomes harder, the bearing surface of the roller decreases and the compressive effect is increased at the time it is most wanted. Iron rollers should be cast in this form as being probably a more scientific shape than any other. Any slight inverts or cusps caused by this roller would disappear under repeated rollings, and by the wear of the traffic.

We now come to the consideration of those Rollers which permit of being weighted up, and for this purpose a stout iron axle running through the body of the roller is necessary. We are limited, consequently, by this consideration to the common English iron roller, and a country roller made up piece-meal with stone wheels similar to those used in grinding chunam. Drawings of these two are given, and a frame work with counterpoise stone boxes shown with the iron roller; the same frame-work does for the stone roller and is not therefore shown with it. These stone wheel rollers cost about Rs. 60 per cent. more than those cylindrically shaped, say Rs. 40 and 25, respectively. Their weight is 3,780 lbs. or 105 lbs. to the inch bearing. One ton can be added to this by means of the framework and stone boxes, which gives 167 lbs. per inch bearing. We are still however far off the weight necessary for rolling metal, for which the iron rollers are most effective. The compressive effect of these stone wheel rollers might be greatly increased by making them barrel-shaped or bevilled, but their construction would not permit of this.

The width of the English rollers is 3 feet, and diameter 4 feet, and the weight about 2 tons. The stone boxes and framework would give another ton; and if the interior be boxed up and filled with scrap-iron, such as unserviceable pickaxe heads, &c., of which every Executive Engineer must possess a quantity, we should have a total weight of say 5 tons, or 311 lbs. per inch bearing These rollers may therefore be depended on for consolidating both moorum and metal. They might be made much heavier by filling the interior with lead, but it seems doubtful whether any corresponding advantage would be gained to counterbalance the increased difficulty of draught.

The stone boxes are useful as counterpoises, which is effected by removing a few stones from one box to the other; as for instance, on an ascent a certain weight removed from the rear to the front box would much facilitate the draught of the bullocks, according to a well known law.

In all the foregoing calculations, it has been assumed that all the rollers insist or stand on an area proportional to their length only; this is not strictly true, and is only the case where the surface of the roadway is perfectly hard and in practice the area is proportional to the diameter of the roller. This is an important fact, as thereby the effect of the larger rollers is considerably reduced. To recapitulate then, and to exhibit the effective power of each kind of roller after taking all the above into consideration, we have the following results:—

No.	Item.	Weight per inch.	Proportion.
1	Cartwheel, say 4 feet diameter on the average,	280	1·000
2	Iron rollers, weighted up, 4 feet diameter, ..	311	1·117
3	Stone wheel rollers, weighted up, 3 feet diamr.,	223	0·796
4	Bevilled or barrel-shaped rollers, 2 feet diamr.,	282	1·007
5	Cylindrical stone rollers, 2 feet diameter, ..	94	0·336

There are many officers in the Indian Engineers, in the three Presidencies, who have had a great experience in Road-making, and if they could be induced to come forward and favor us with the results of their knowledge in the treatment of metal of all sorts,—kunkur, laterite, and other materials which are used for roads,—they would expedite the public service by opening up an entirely new subject, and enabling the operations to be conducted in a scientific manner.

MHOW, 1st *October*, 1865. A. C.

ISIONS OF THE ...H OF MAY, 1864.

...nrersal.	Hill Roads.	Lower Sir...	Branch Roads.	Salt Range Division, Pind Dadan Khan.	Delhi & Goorgaon Irrigation Works.	Hansi Division, Western Jumna Canals.	Indus Canals Division.	Sutlej and Chenab Division, Inundation Canals.	2nd Division, Baree Doab Canal.	Delhi Division, Western Jumna Canal	Rohtuck Division, Western Jumna Canal.
0 0	15 to 20*r*.	15	...	20 0 0	15 0 0	...	...	...	...	15 0 0	...
8 0	0 6 5	0	...	0 8 0	0 8 0	...	...	...	...	0 8 0	...
6 6	0 5 4	0	...	0 6 0	0 6 0	...	...	...	...	0 6 0	...
0 0	...	15	0 0	20 0 0	12 0 0	10 0 0	20 0 0	15 0 0	15 0 0	12 0 0	8 0 0
6 0	...	0	6 0	0 8 0	0 8 0	0 5 0	0 8 0	0 10 0	6 to 7*a*.	0 8 0	0 4 0
4 6	...	0	5 6	0 6 0	0 4 0	0 4 0	0 6 0	0 8 0	4 „ 5*a*.	0 4 0	0 2 0
	15 to 20*r*.	15	0 0	20 0 0	15 0 0	10 0 0	30 0 0	15 0 0	20 0 0	15 0 0	12 0 0
	5-4 „ 6-5	0	6 0	0 8 0	0 6 0	0 5 0	0 8 0	0 10 0	0 8 0	0 6 0	0 4 0
	4-3* „ 5-4	0	5 0	0 6 0	0 4 0	0 4 0	0 6 0	0 8 0	5 to 6*a*.	0 4 0	3-2½-2*a*.
0 0	15 0 0	15	0 0	20 0 0	15 0 0	10 0 0	30 0 0	15 0 0	40 0 0	12 0 0	10 0 0
6 0	0 6 5	0	6 0	0 8 0	0 4 0	0 5 0	0 8 0	0 10 0	7 to 8*a*.	0 4 0	0 5 0
5 0	0 4 3	0	5 0	0 6 0	0 3 0	0 4 0	0 4 0	0 8 0	0 5 0	0 3 0	4 to 3*a*.
5 0	...	0	6 0	0 8 0	0 4 0	0 4 0	0 6 0	...	...	0 4 0	0 4 0
5 0	...	0	3 6	...	0 3 0	0 3 0	0 4 0	...	...	0 3 0	0 3 0
2 6	...	0	3 0	0 4 0	0 2 6	0 2 0	0 2 6	0 6 0	0 2 6	0 4 0	0 2 6
2 0	0 8 0	0	3 0	0 4 0	0 4 0	0 2 0	0 4 0	0 5 0	2½ to 4*a*.	0 4 0	0 2 6
3 0	0 6 5	0	5 0	0 7 0	0 4 0	0 3 0	0 4 0	0 5 0	0 3 0	0 4 0	0 2 0
2 0	4-3*to5-4	0	3 0	0 3 0	0 2 0	0 1 6	0 2 6	0 4 0	0 2 6	0 2 0	1½ to 1¼*a*.
	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	0 6 0	...	...	...	...	...	...	...
	...	...	...	0 2 6	...	...	...	...	...	5‡ 0 0	...
	8‡ 0 0	...	...	...	...	...	...	...	...	...	...
0	...	7 12	0 0	...	12 0 0	...	4 0 0	10 0 0	7½ to 8*r*	10 0 0	...
0	...	5 (	0 0	...	...	...	3 0 0	6 0 0	...	7 8 0	...
0	...	7 (	...	...	6 0 0	...	...	8 0 0	6½ to 7*r*.	6 0 0	...
0	...	5 (	...	...	...	...	...	...	...	4 0 0	...
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At site of work.

No. XCII.

THE GREAT TRIGONOMETRICAL SURVEY OF INDIA.

(2ND ARTICLE.)

Compiled from a Return to an order of the House of Commons. BY LIEUT.-COLONEL A. S. WAUGH, R.E., *Surveyor General (*1850*)*.

BREVET Captain Du Vernet, of the Madras Army, who had previously been employed on the Hyderabad Topographical Survey, was appointed to the Trigonometrical Survey in the year 1840, and in the year 1841 proceeded to prosecute the triangulation of the Himalaya Longitudinal Series, extending from the Great Arc along the southern tace of the sub-Himalayan range, so as to connect the nothern limits of all the meridional series. This work, together with the Pilibit series, conducted by Captain Waugh, forms a portion only of the "North Longitudinal Series," under which head it will be discussed.

Previous to Colonel Everest's departure, Captain Du Vernet was ordered to continue the North Longitudinal Series, between the meridians of Amua and Karara, which he successfully accomplished in one season. During the year 1844-45 he was employed in prosecuting the triangulation from the north along the meridian of Karara, to form a junction with Captain Shortrede, who was working from the south, as already explained.

On the termination of this duty, Captain Du Vernet was directed to take up the Gurwani Meridional Series, depending on a side of the Calcutta longitudinal series. This work commenced in 1845-46, and was accomplished in two years. The area embraced is 6,298 square miles. In this series was employed for the first time a 24-inch Theodolite, made up by the Surveyor General from various materials belong-

ing to Government, and lying useless in store, the fundamental part being a 24-inch circle hand, divided by Mr. Simms, formerly appertaining to the astronomical circles It was fitted up with five micrometers, and the results showed that it was capable, in good hands of measuring angles to half a second of the truth.

On the completion of the Gurwani meridional series, Captain Du Vernet with his establishment was transferred to the North-West Himalaya series, proceeding from the Great Arc to Peshawur. This work was intended to form the foundation of the triangulation of the newly conquered Province of the Punjab, and its progress will be detailed further on.

On the termination of the Great Arc, the two parties which had been engaged on that work were reduced, and placed respectively under the charge of Mr. George Logan, a Surveyor of experience and ability, and of Mr. James, principal Sub-assistant. These parties were deputed by Colonel Everest before his departure, to take up the Chendwar meridional series, and the Gora meridional series, dependent on sides of the Longitudinal series, both of which were completed by 1846.

On the conclusion of the Budhon series, Captain Renny Tailyour was ordered to take up the Maluncha meridional series, dependent on a side of the longitudinal series, which was completed by Lieut. Reginald Walker of Engineers in 1846.

The Calcutta Meridional series was commenced at the base line in 1844, by Mr. Sub-assistant Lane, in 1848. The series in its whole extent traverses the alluvial plains of the Ganges, in which great difficulties had to be surmounted. The instrument employed was an 18-inch theodolite, by Troughton and Simms. On closing at Sonakoda base the linear error amounted to 0·64 feet in seven miles, from which is inferred an average error of 0·09 foot per mile; which considering the size of this engine-divided instrument, and the extent of triangulation, 260 miles, entirely in a flat marshy country, may be considered creditable. The area comprised amounts to 4,136 square miles.

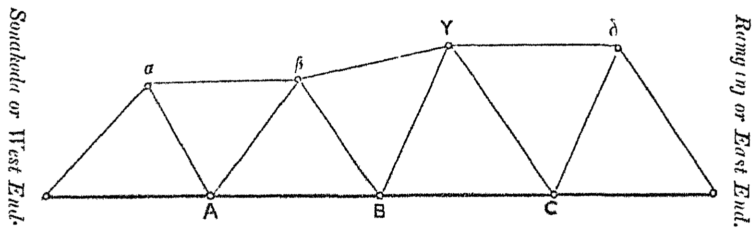
In the year 1845, Captain Thorold Hill, of the Madras army, who had formerly been employed in the Madras Topographical Survey, was nominated by Government to succeed Captain Shortrede. He was

deputed to the charge of the Coast series, intended to extend from the the Calcutta base line to the Madras Observatory, according to Colonel Lambton's original design. For this work Capt. Hill was supplied with a new 24-inch theodolite, of which four had lately been made by Mr. Simms for the Indian Survey, and graduated by his new self-acting apparatus. Colonel Lambton, in his project for this series, contemplated that great difficulty would be experienced in carrying it over the flat lands between Balasore and Calcutta, and the obstacles proved as great as that officer anticipated. The low lands are covered with water, and very unhealthy till December. During the cold season fogs are prevalent, and at the vernal equinox, as well as during the hot season, tornados, or circular hurricanes, are of frequent occurrence, producing the most devasting effects. During one season the whole tent equipage of the party was utterly destroyed. The country is not only flat and covered with groves, but intersected with creeks and marshes, which renders triangulation both slow and expensive. On the other hand, the unhealthiness of the climate was such that every season the party was driven away by sickness, and Capt. Hill's health suffered so much that he was compelled to proceed to sea for two years. From all these causes combined, progress was very slow.

The North Longitudinal Series extends from the Dehra Doon base to the Sonakoda base, a distance of 690 miles along the frontier. This work has been executed by various parties at different times. The first part from the Great Arc series to the Ranghir series, was executed by Captain Du Vernet, as already stated. The next portion, between the Ranghir and Amua series, was completed by Capt. Waugh, prior to his succeeding to Colonel Everest. The part between Amua and Karara was executed by Captain Du Vernet, but on account of some defect in the instrument was not considered satisfactory, and was revised by Mr. Logan, who completed the whole extent as far as the Chendwar series, under great difficulties as regards climate and forest, from which his party suffered greatly. The whole of this portion is excellent, having been executed with Barrow's great Theodolite, by Mr. Logan himself. From Chendwar to Muluncha series the work rests on Messrs. Peyton's and Nicolson's observations, with a 24-inch Theodolite by Barrow. The remaining portion from Maluncha series to Sonakoda

base depends on Lieutenant Walker and Mr. Lane's observations, with Troughton's great Theodolite.

In the year 1847-48 the Sonakoda Base line, was measured for the verification of the North Longitudinal and the Calcutta Meridional series, as well as to furnish a new basis for the extension of operations into Assam, and up to the extreme frontier of British India on the east. This base line was very satisfactorily measured with Colby's compensation apparatus, and being proved by minor triangulations, in four sections, exhibited the following results.



Scale—2 Miles to an Inch.

Each Section of the Base compared with the whole Base.

	West end to A.	A to B.	B to C.	C to east end.
Measured length, inches, ...	109625·15	110381 17	116428 94	103794·45
Computed from the whole base, do,	109625 00	110381 17	116429·03	103794·51
Error, inches, ...	+ 0 15	0 00	— 0 09	— 0 06

Each Section compared with the other Sections.

Measured length, inches, ...	109625·15	110381·17	116428·94	103794 45
Computed from 1st section, „	...	110381·32	116429·20	103794·65
„ 2nd „ „	...	...	116429·03	103794·51
„ 3rd „ „	...	...	...	103794·43

The area comprehended by the North Longitudinal Series amounts to

15,826 square miles, exclusive of the mountain operations in Sikim and along the frontier, which cover a further area of 73,920 square miles, giving a total of 89,746 square miles.

Captain Renny Tailyour, while in England, made himself acquainted with the progress of the Ordnance survey, and returning to India in 1847, gave his assistance at the Base line, after which he was deputed to proceed to Sironj with Troughton's great theodolite, for the purpose of extending the great Longitudinal series from the Sironj Base to Karachi in Sind. Some account of this important series will be given below.

After the conclusion of the Bombay Longitudinal series, Captain Jacob proceeded to England on sick certificate, and was succeeded by Lieut. Harry Rivers, of the Bombay Engineers, by whom the Trigonometrical operations in that presidency were conducted for some time. These consisted of the South Konkan series, dependent on a side of the Bombay longitudinal series. This work was completed between the years 1842 and 1844. After its conclusion Lieut. Rivers took up the North Konkan series, in the prosecution of which the health of his party suffered so much that it became necessary to withdraw from it when it had attained the parallel of 21° 54′. He next took up the Khanpisura series on the meridian of 75°, which he continued up to Ajmere. The area comprised in these several operations conducted by Lieutenant Rivers, amounted to 45,854 square miles.

[The following observations by Colonel Waugh, on the general state of the work up to 1850, have been abridged from his report for that year, and will be found interesting to read before proceeding with the subsequent history of the Survey].

The accuracy attained by the modern operations may be thus briefly stated. In the large triangulation, where of course the greatest refinement and most scrupulous care is observed, an error of one inch per mile, or $\frac{1}{63360}$ part, amounts to 500 inches or 42 feet, or nearly half a second in arc of latitude or longitude in 500 miles, which distance is even exceeded between some of the bases. The work is reckoned liable to half this error when executed with the great Theodolite on the principle of double series; the results attained by the new 24-inch theodolites are but little inferior to this degree of accu-

racy. When the series are single, the liability to error is reckoned to approach nearer to one inch per mile; when performed with good 18-inch theodolites, the error will exceed one inch per mile, according to the character of the graduation. With inferior instruments, or a less careful system, the accumulation of error would approach a foot per mile, which is equal to a ratio of $\frac{1}{5280}$ in linear dimension, or $\frac{1}{2640}$ in area, or $\frac{1}{20}$ per cent., or six seconds of arc in the above distance.

In reviewing the whole progress of the Trigonometrical Survey of India from its commencement by Colonel Lambton to the year 1848, it appears that the grand total of area triangulated amounted to 477,014 square miles, and the grand total of cost to Rs. 34,12,787, or say £312,389, showing an average cost of Rs. 7-2-5 per square mile, or about 13*s.* 1*d.*, which cannot be but considered remarkably moderate, especially when the nature of the country and climate, as well as the absence of all the usual resources to be found in Europe, are taken into account. The hardships and exposure of surveyors working in the field for the greater part of the year, in such a climate as India, are either little known or little appreciated. They have on several occasions kept the field throughout the year. The duties of the trigonometrical survey likewise are often unremitting day and night, because the best observations are obtained during the nocturnal hours, when the dust raised by hot winds subsides, and the atmosphere becomes clear and calm.

The total area of British India as it stood in 1850, including Sind, Punjab, the and Tenasserim, was carefully estimated at 800,758 square miles,* and the native states at 508,412 square miles, making a grand total of 1,309,200 square miles as the area of survey. A complete delineation of this vast superficial extent, amounting to $1\frac{1}{3}$ million of square miles, confined within an external boundary of 11,260 miles in length, including every variety of configuration and climate, is an undertaking of unprecedented magnitude, demanding considerable time to accomplish with any pretensions to mathematical accuracy. The exertions hitherto made have been unremitting, and it is but justice to say that the progress has been, generally speaking, as honorable to the officers employed as the results have been useful to the country.

* Since then, the great Provinces of Oudh, Pegu, and Nagpore, have been added.—[ED.]

The programme of future operations, as laid down by Col. Waugh in 1850, was as follows:—According to Colonel Everest's design, an ellipsoidal space is included between the great arc on the west, the Calcutta meridional series on the east, the great longitudinal series on the south, and the north longitudinal series along the frontier; which are verified by four base lines at their origin and termination; all measured with Colby's apparatus. This immense ellipsoidal area is filled up by subordinate meridional series nearly one degree of longitude apart, which series depend on the Great Longitudinal series for origin, and on the North Longitudinal for verification. This has been denominated the gridiron system, and obviously possesses superior facilities for rapidity and accuracy. This design of Colonel Everest's has been completed and the country to the west of the Great Arc is intended to be triangulated on precisely the same principles—1st, The North-West Himalaya series will extend from the Dehra Doon base line to Peshawur, where it will be verified by a measured base; 2ndly, the Great Longitudinal series will be extended from the Sironj base to Karachi, where a base will be also measured,* 3rdly, between the Attock and Karachi bases extends a great meridional series,† between which and those before described is included an immense ellipsoidal area, averaging 9° of latitude by 10° of longitude. As all the bounding series will be executed with superior instruments and duly verified by base lines, whereby limits are placed to the intrusion of error, those series will be fit to verify the subordinate meridional series by means of which the intermediate space is intended to be rapidly filled up at every degree of longitude apart, according to Colonel Everest's system.

To the east of the Calcutta meridian it is proposed to extend the North Longitudinal series, from Sonakoda base into Assam. From this series will depend other meridional triangulations at one degree apart, upon which the accurate geographical delineation of eastern Bengal will be based.

The Bombay party will complete the remaining triangulation of that presidency in a few years. There only remains, therefore, to be considered the vacant space to the south of the Calcutta longitudinal

* Since completed.—[ED.] † The Indus series, since completed.—[ED.]

series, in which is embraced the hill country of Gondwana and tributary mahals, between the sources of the Son and Narbada, the Godaveri river, and the sea. This region, inhabited by aboriginal tribes, is unhealthy in the extreme, and of no value; but from its rugged configuration, any survey not based on triangulation would accumulate vast errors. It is proposed to triangulate this region by meridional series at every two degrees apart, filling up the interstices with secondary triangulation. In this way that space can be most rapidly surveyed.

The instrumental equipments are admirably adapted for the work in hand, and in 1850, consisted of the following apparatus .—

1 Colby's compensation apparatus for measuring base lines.

2 Great theodolites, 36 inches diameter, by Troughton and Simms, and Barrow, respectively.

4 24-inch theodolites, by Simms and Barrow.

2 18-inch theodolites, by Troughton and Simms.

6 14-inch Vernier theodolites, by Simms.

6 12-inch theodolites, by Troughton and Simms.

20 7-inch theodolites, by Troughton and Simms.

2 Astronomical circles of 3-feet diameter, by Troughton and Simms.

5 Astronomical clocks.

14 Chronometers.

The signals consist of Argand lamps and Heliotropes.

With regard to the rate of progress, much depends on the efficiency of the officers, and on the accidents of climate to which the parties are so much exposed. In a hilly country, the average advance made per season by each party is about 120 miles in length by 30 in breadth, or say 3,600 square miles. In a flat country the average is 80 miles in length by 12 in breadth, or about 1,000 square miles. The average for both kinds of ground may be taken at the mean, or 2,300 square miles.

As to the land surveys by which the interior is filled up. The greater part of the Madras peninsula has been taken up on the basis of the great triangulation, by means of minor triangles and military plane table surveys, executed on a scale of one inch per mile. This style of work is remarkably cheap, the cost per square mile not exceeding Rs. 6, or less than 12*s.*; and in favorable localities, free from jungle fever, which is the dire enemy of all survey operations in India, the expense

becomes much lower. This kind of survey being based on triangulation cannot accumulate error, and gives an admirable representation of the land, but it requires good draughtsmen, who are difficult to be obtained in India. The system is peculiarly adapted to mountainous countries, where the value of the land being small, an expensive system is inapplicable. It has already been extensively carried out in the native states, and it is proposed to extend the same principles to the remainder.*

The Revenue Survey of Bengal commenced in the year 1822, and consists of the measurement of the boundaries of estates, which are executed by theodolite and chain, upon the traverse system. Up to the year 1830, the rate of progress at which the operations proceeded was extremely limited, only 3,020 square miles or little more than half a square degree had then been performed in seven years, with ten officers employed in the department, the annual rate of progress of each surveyor ranging from 50 square miles to 338 as a maximum. The officers employed in those days, however, had little or no assistance, and the duties performed then by the revenue surveyor himself, are now entrusted to competent Assistants and Sub-assistants, with large native establishments under them, whilst the Surveyor acts as a superintendent over the whole; the result of which has been, that since 1830, the whole of the North Western Province districts, all Behar and Orissa, and a considerable portion of Bengal proper, have been completed.*

As respects the accuracy attainable by the measurement of the Revenue Survey, it may be stated generally that the maximum error allowed in linear dimension, according to the test it is submitted to by traverse proof, is 10 links in 100 chains, equal to 5 28 feet per mile; but in the actual prosecution of the extensive surveys of the season 1847-48, covering an area of about 16,000 square miles, the average ratio of correction employed for the closing of the traverses is found to be only two feet per mile, or rather more than one-third of the allowed correction: $\frac{1}{10}$ per cent., therefore, for the pergunnah or main circuit measurement is fully within practicabillity; $\frac{1}{10}$ per cent. also may be allowed for the area of the district; $\frac{1}{2}$ per cent. for the village survey area, and 1 per cent. for the interior detail measurement of cultivation and waste. But the most severe test to which a Revenue

* Col. Waugh's Report of 1850.

survey can be subjected is, the comparison of its results with those of the Trigonometrical survey ; and that this comparison may be performed as readily as possible, a due and proper connexion between the two surveys is essential, and is now scrupulously maintained.

The azimuth of any side of the large triangles likewise proves a check on the deduced azimuth of the revenue survey, as conveyed from one main circuit to another, and this comparison is carefully carried out when opportunity is afforded for so doing.*

It will be apparent, from the foregoing statements, that the Revenue surveys supply the interior filling up of the triangles in the British revenue districts, which are chiefly flat lands, to which that system is most applicable. In native states and wild hilly countries, the Topographical surveys before described are admirably adapted to the object in view, which is a complete and inexpensive first survey of all India. Considered in this point of view, the work may challenge comparison with any in the world. The Triangulation supplies a permanent and accurate basis for the present, as well as for future internal surveys ; for it must be borne in mind that, as the resources of this country become developed under the fostering protection of British rule, the topographical aspect of many districts must, in a moderate number of years, be completely changed. Tracts now covered with jungle will be reclaimed, canals will be dug, marshes drained, and roads established. New towns and villages will arise, fresh groves be planted, and rivers will change their course. That these views are not chimerical may be attested by experience, for places where the tiger, the bear, and the boar, were formerly hunted are now covered with fields, yielding a plentiful harvest to the cultivator. The greatest difference is also perceptible in the extension of towns and villages, showing the increase of productive wealth which is taking place on all sides. These alterations cannot but produce, in the course of time, considerable changes in the topographical features of the country, for which reason revised surveys will be required, and these, like the present ones, will be based on the operations of the Great Trigonometrical Survey of India, which are intended to form a lasting monument for future generations, and an imperishable record of the landmarks of the present time.*

(To be continued.)

* Col. Waugh's Report of 1850.

Correspondence.

The Editor acknowledges, with thanks, the receipt of the following Papers:—Loondehara Tunnel—Kurrumnassa Bridge—Levelling Operations of the G. T. Survey—Machinery for Punkahs—Nagpore Church—Rawul Pindee and Murree Road—Progress of the G. T. Survey from 1800-1850.

To the Editor.

Poona, November 30th, 1861.

Dear Sir,—Sir William Mansfield's attention having been attracted by the para. and note in your article on the Finance of Engineering, relating to the employment of Soldiers, the Regimental Workshops, &c., His Excellency thinks it may be agreeable to you, with regard to following out the subject hereafter, to learn what has been done in the Army of the Bombay Presidency.

I have therefore received his directions to enclose certain printed papers showing the economical effect of such labor in the Bombay Army, by applying the principle of free labor. The two illustrations of Mhow and Asseerghur are highly satisfactory. It is pleasing to know that through adherence to the principles of voluntary labor and free competition, the institution of Regimental Workshops seems to be really taking root with great advantage to the individual soldier, and in a manner not contemplated by the originators of the system, but affording the further result of checking estimates and tenders from the bazars in a manner which had not been anticipated by the originators of the institution.

Barrack furniture, repairs of barracks, &c., are now being completed in many stations of this Army by the European Soldiery, according to free tenders, which are accepted by the Departmental Officers if they be advantageous. No favor or affection is shown, and all parties seem to be satisfied.

With His Excellency's sanction this principle is now being applied to the Native Regiments, experimentally; but Sir William Mansfield is sanguine of being able to organise a labor movement throughout the Native Army which will occupy the time of the men, and add considerably to their emoluments.

The experiment has been commenced at Poona; many hundreds of the Sepoys having been employed on the Government Works, voluntarily on their part, the men

so employed received the wages of the market. They are not permitted of course to evade either duty or drill; but by the employment of their leisure hours at such task work as they can obtain from the Executive Engineer, they have been able to earn several rupees per month per man to their own great satisfaction. The Executive Engineer has been highly satisfied with their work, which is much more rapid than that of ordinary laborers, in consequence of their habits of discipline, and of its being therefore easier to obtain larger joint results from them as a body working together than is generally observed amongst native workmen.

Believe me, &c.,

R. PHAYRE, LIEUT.-COL.,
Qr.-Master Genl. of the Army.

(Enclosures in the above letter.)

MEMORANDUM REGARDING THE EMPLOYMENT OF THE EUROPEAN TROOPS UPON PUBLIC WORKS AT ASSEERGHUR.

1. When sanction was received, in September last, to proceed with the Iron Shelves in the Asseerghur Barrack, the Native Blacksmiths proved unequal to the task, and competent European Smiths were found in the Detachment of Her Majesty's 33rd Regiment at that Station. The Native Carpenters (those employed upon Contract Work excepted) were also unequal to the work of making the Arm-racks, and European Carpenters were found for that purpose. Again, in the removal of the slab stone eaves from the roof of the old Musjid, the Native laborers could not do it, and Europeans were employed.

2. During the month of October, fever in the Pettah caused serious reductions in the muster of all classes of Native labor, and the Railway Agents about the same time made their appearance with large sums of money, and enticed away some of our unskilled labor at high rates of pay,—in fact as high as seven (7) annas per day for a biggarie. To sit down and see the works come to a stand-still was out of the question; equally imprudent would it have been to compete with the Railway for labor. Lieutenant Mant, while here, increased the biggarie's pay from 3 to 3½ annas per day, and as subsequent increase to 4 annas failed in inducing some of the work-people to remain, our only recourse became the employment of the Soldiers. It was found that the Detachment could furnish as follows :—

2 Carpenters—2 Blacksmiths, 1st Class—2 Blacksmiths, 2nd Class—4 Stone Masons —2 Sawyers—1 Glazier—and from 50 to 60 Laborers out of a total strength of about (90) ninety. The Sergeants do not work, as none of them are Mechanics, and it would not be prudent for them to work as laborers. A Non-Commissioned Officer is however employed as Time-keeper with the laborers. The following rates of pay were adopted from the first, viz :—

	R.	A.	P.
1st Class Blacksmith, per day	1	4	0
2nd " " 12 annas per day, ...	1	0	0
Carpenters, per day, ...	1	4	0
Laborers, working from 8 A. M. to 5 P. M., ...	0	12	0
" " 8 to 10-30 A. M. and from 2-30 to 5 P. M., ...	0	8	0

Those men only who could work under cover have been allowed to work all day. The work performed by the men of the Detachment consists of—

1. Plaster to half the Left-half Barrack 8,500 superficial feet.
2. Completing paved floor of „ 1,500 „
3. Whitewashing Left-half Barrack.
4. Paving water-room to Left-half Barrack.
5. White-washing „
6. Iron-shelves to two half Barracks.
7. Arms-racks to „
8. Arms-racks to the old Musjid (temporary Barrack).
9. Petty repairs.
10. Removing slab-stone eaves of the old Musjid.
11. Excavating moorum floor of Right-half Barrack.
12. Making footpaths in European Lines.
13. Collecting tiles from sites of old Pendalls and placing them on the roof of the Left-half Barrack.
14. Levelling sites around the new Barracks.
15. Demolishing old Native Infantry Pendalls.
16. Demolishing other old Buildings.
17. Glaziers' work to the new Barracks.
18. Repairs to Barrack Furniture.
19. Iron doors to Solitary Cells.
20. Iron windows to Quarter Guard.
21. Carrying dressed stone from Quarry to Barracks.
22. Drawing Carts laden with stone „ „
23. Repairs to the Road inside the Fort Gate.

3. The men have worked well, and conducted themselves admirably, always sober on the works without exception, and strictly obedient in the performance of whatever work may be pointed out to them; without the aid of the Troops it is almost impossible to say when the Barrack would be completed.

4. It deserves particular mention that the Europeans will work as laborers to Native Masons in carrying stone, bricks, mortar, &c, &c., and that no complaints have been made by the Native women, who were rather shy at first of working near the Soldiers.

5. Captain Trent's presence amongst his men, every day, while employed upon the Public Works has materially added to the success of their employment.

6. Of the value of the European labor, employed at Asseerghur, as compared with that of Natives, it may be remarked that the works, numbered 1 to 5, 9, 11, and 13 to 23 inclusive, have been carried out within the estimated rates, and, in some instances, cheaper than they could have been by Native labor, notwithstanding that Tools had to be made, or provided especially for the Europeans, and that the cost has been included in the accounts of their works.

(Signed) W. F. KNIGHT,

Supervisor, Public Works Department.

Asseerghur, 18*th December*, 1863.

Report by order of his Excellency the Commander-in-Chief.

Head Quarters, Bombay, 22nd February, 1864.

This Memorandum, forwarded by the Officer in supervision of Public Works at Asseerghur, under date the 18th December, 1863, with regard to works performed by Soldiers of Her Majesty's 33rd Foot at that Station, is considered a most satisfactory illustration of the development of the Workshop system, which has been yearly gaining strength in the Artillery and the several corps of Her Majesty's Forces serving in India, and goes to show that wherever European troops are stationed, the very best description of skilled, as well as ordinary labor is available; in this instance at a cheaper rate than the Native labor could be obtained—one consideration only being essentially necessary, viz., that the men should not be exposed during the day. Although in some cases shops have not thriven so well as in others, it is known that opportunity is alone wanted to develope them. In every Battery and Regiment the organization is complete, and application has only to be made to Commanding Officers to receive prompt attention, they being quite alive to the good results which follow the employment of their men, and consequent relief to the men from the monotony and tedium of an unemployed life.

The system of Workshops is founded on the principle of voluntary labor, the same being afforded for what it is actually worth It is strenuously ordered and enforced that no favor is to be given to the Soldiers, and that they must depend entirely on underselling the Native artizan,—this being shown both in price and the quality of the work, and the amount done.

The Public Works, Commissariat or Barrack Departments, can take the tenders of the Workshops or not as they please, according to such a principle. It is, therefore, absolutely necessary, in the Commander-in-chief's opinion, that the principle should be preserved intact, and that the soldier should obtain all he can thus earn without regard to a working pay system, which was designed to meet the necessities of an opposite principle. That principle rests on the fact that under certain circumstances of service, the Soldier can be ordered under the Articles of War to perform particular kind of skilled work. The order having been obeyed, he receives a moderate remuneration for the time thus spent, the work which he has performed being, in point of fact, an extra Military duty. This is a very different thing from the development of voluntary labor. There can be no doubt that to recur to it would at once shut up every Workshop in Her Majesty's Regiments, and so defeat one of the most useful reforms which was ever introduced.

The distinction between an Infantry Regiment, which is recruited merely for Military duty, and of enlisted Sappers and Miners, who receive higher rates of pay and according to particular rule of scales, puts skilled labor at the disposal of the State, is, His Excellency thinks, too obvious to require further disquisition on his part.

By order of His Excellency the Commander-in-Chief,

T. STOCK, Lieut.-Colonel,

Adjutant General of the Army.

Public Works, Execution of, by Contract by Troops.

Bombay Castle, 13th April, 1864.

Resolutions.

1. Government have had lately under consideration a case where very valuable assistance was afforded by the detachment of Her Majesty's 33rd Regiment, in the execution of Public Works at Asseerghur.

2. Government consider that the arrangement, which in this case has proved so very successful, might with great advantage both to the State and to the soldiers, be adopted elsewhere in expansion of the workshop system, which has already been established.

3. Government are therefore pleased to direct that at all stations where there are European Troops, the Executive Engineer, on receiving sanction for a work that might with advantage be executed by such agency, shall communicate with the Commanding Officer, and shall indicate the nature of the work to be executed, its probable cost, and the period within which it should be completed, and at the same time invite a tender for its execution by contract by the Troops.

4. If the tender by the Troops is too high, or higher than any which may have been received for the same work from any other person, it may be rejected; but if it is favorable in all respects it should be accepted. It being clearly understood on both sides, that in any arrangement of this nature, the ordinary rules of trade must be attended to; that the workshops must compete in the open market, and depend for their success on underselling the native tradesmen, and manufacturers; and on such terms make what profit they can.

5. Much of the success of the plan will depend on the manner in which negotiations are conducted between Commanding Officers and Executive Engineers. A hearty co-operation is both necessary and desirable, if the wishes of Government are to be fully carried out, and while enjoining this spirit in treating this question on the part of the Officers of the Public Works Department, Government desire to move His Excellency the Commander-in-Chief to issue such directions as he may deem best, to ensure a like feeling on the part of Commanding Officers.

6. A quarterly report should be made to Government of all works performed by European soldiers, which should be in the form of a concise narrative of the progress of the works to which it relates, accompanied by a tabulated form showing the quantity of each particular item of work performed, its cost, and a brief specification of its nature. This return should also show the average strength of soldier-artizans, and laborers daily, employed on the works.

7. Government consider Mr. Supervisor Knight deserves great credit for his arrangement in regard to the work performed at Asseerghur by the soldiers of Her Majesty's 33rd Regiment.

(Signed) M. K. Kennedy, Lieut.-Col., R.E.,
Secretary to Government.

The other case referred to in the above letter is too long to print, but is as satisfactory an example of the economy and utility of Regimental

Workshops, as the first case is of the advantage of employing soldiers upon Public Works.

In the article referred to by Col. Phayre, I expressed an opinion adverse to amateur, *i. e.*, voluntary, work of this kind, which I am very glad to have corrected on such good authority.

It is a minor question, whether the profits of such work should be enjoyed by the soldier alone, or whether they should be shared by the State. The main point to be insisted on I take to be, that soldiers can be occupied either on Public Works or in Regimental Workshops to the mutual advantage of themselves and the State, and without any diminution of their efficiency as soldiers. If this can be done by voluntary means, as in the two cases above quoted, no doubt it is best—if not, I believe it should be insisted upon as part of the duty of a soldier just as much as his parade duties or rifle drill.

But when Commanding Officers so seldom recognize the importance of their men being adepts in such strictly military work as the use of entrenching tools and the construction of field works,* and, indeed, as a rule greatly dislike their men being employed in any such work, how can it be hoped that they will cheerfully encourage their working as laborers on roads, as masons on buildings, or even as carpenters in their own workshops?

It all depends on the Officers—let the feeling be once established that *all* kinds of work useful to the efficiency of an army are as honorable as actual fighting and as much part of a soldier's duty, and there will be little difficulty in the matter; and it is most encouraging to see that the attempt is being seriously made in at least one of our armies. I believe that such employment is a corollary to the Regimental schools. It is of no use educating men unless you give them vent for their awakened energies, or at least for their physical powers. You simply make them dissatisfied with their position. The large number of time expired men who are now taking their discharge, seems to show this.—[ED.]

* There are few Engineer Officers who have had to superintend line working parties at a siege who do not know this, and yet who would not also bear witness that the smartest Regiments in the battle field also furnish the best working parties. Why should not *every* Regiment be employed during part of the cold weather in field works?

Correspondence.

THE Editor acknowledges, with thanks, the receipt of the following papers:—Public Works Progress Report for 1863-64—Report on the Gogra—Brick-making in the Tropics—Design for a Canal Fall—Railway Institute, Lahore.—Laying out Curves—The Yangul Bridge.

NOTICE TO CONTRIBUTORS.—Any Contributor who may desire to have a few extra copies of his own paper, can be supplied *gratis* on application to the Editor in time.

To the Editor.

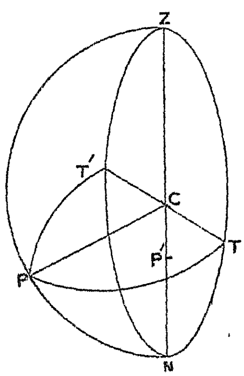
SIR,—Will you be good enough to explain how I am to construct a perpendicular Sun Dial, such as are erected on the south face of some village churches at home—say for N. Lat. 31° 30′? It is an easy matter to make the calculations for the ordinary horizontal dial, but I can find no book that gives instructions in respect to the other.

Banks of the Ravee, *February* 15*th*, 1865.

Your obedient Servant,
PUNJABEE.

To construct a prime vertical Dial.

Let TNZ be the plane of the Dial produced to cut the celestial sphere.



P the pole of an opposite name for the latitude, PZN the plane of the meridian, and CPT the plane of an hour circle, and CP the direction of the style. Then PN is the co-latitude, and TCT′ the hour line corresponding to that meridian, which gives the hours of the same name at T and T′ in the forenoon and afternoon. Let $l =$ the latitude, $h =$ the hour angle in degrees, $c =$ the co-latitude PN. Then we have in the spherical triangle PNT.

Cot h : rad :: cos l : tan t, where t is

the angular distance of the hour lines in succession from the hour line of noon, or

$$\log. \tan t = \log. \cos l + \log \tan h - 10.$$

Example.—To construct a vertical Dial for a place in latitude 31° 30′ Angular distances of the hour lines from noon will be—

For 1 P.M. or 11 A.M.	$\tan t = \cos 31° 30' + \tan 15°$
12° 52′	$= \tan 12° 52'$, nearly.
For 2 P.M. or 10 A.M.	$\tan t = \cos 31° 30' + \tan 30°$
26° 12′	$= \tan 26° 12'$
For 3 P.M. or 9 A.M.	$\tan t = \cos 31° 30' + \tan 45°$
40° 27′	$= \tan 40° 27'$

and so on.

The angle formed by the gnomon with the vertical face of the dial will of course be 58° 30′ (= co-latitude.)

A correspondent from the Central Provinces, writes:—

"With reference to a paragraph in a paper by you in No. V., I take this opportunity of telling you that we have recently built a large covered saw pit (for 10 pairs) for the shops of this subdivision, and the men have taken to it well. The top sawyers stand up to their work like Englishmen and men, instead of sitting down as they all do hereabouts."

Correspondence.

THE Editor acknowledges, with thanks, the receipt of the following papers:—Indus Silt Experiments (2nd Paper)—Reports on Indian Railway Gauge—G. T Survey Report for 1863-64—New Police Courts, Bombay—Ghaut Tracing in N. Canara.

NOTICE TO CONTRIBUTORS.—Any Contributor who may desire to have a few extra copies of his own paper, can be supplied *gratis* on application to the Editor in time.

To the Editor.

SIR,—I have just seen No. VII. of your "Papers," containing an elevation of a Clock Tower for Umritsur. It is not mentioned in the letterpress, whether this Tower has yet to be built, or whether the work is in progress, or has been completed. If the Clock has not yet been set up, I would offer for the consideration of those concerned this opinion, that if the intention of placing in this Tower the dials described in the Report be carried out, disappointment will be the result, for 5 feet dials are not at all adapted for such a situation

The Tower is described as being 133 feet in height; and, accordingly, the drawing gives the height of the clock dial as about 76 feet from a platform, which is itself raised 10 feet above the ground level.

For such an elevation as this, the clock dials should not be less than 8 or 8½ feet in diameter, in order to be clearly visible from ordinary distances. Consequently, the proposed 5 feet dials, would only offer to view an area of 19½ square feet, instead of a proper area of 50 square feet!

It is mentioned in this report, that the Tower was originally projected of a height of 100 feet, and proportionately the dial in this design would have been about 57 feet above ground. A dial from this height, not counting the platform, would be 5½ feet in diameter, and probably the dials mentioned in the estimate were intended for this height, whereas they are totally unfit for their new position.

Your obedient Servant,

POONAH.

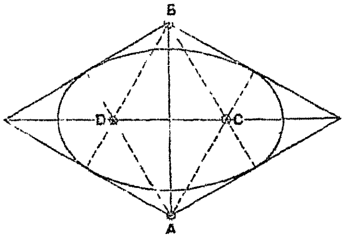
May 24th, 1865.

The Clock Tower is still under construction, and "Poonah's" remarks will no doubt be duly considered by the Architect.—[ED.]

A correspondent sends the following :—

No doubt, most people have found in Isometrical Projection, that, however simple the method may be when dealing only with straight lines, there is a considerable amount of time and patience required in delineating curves; especially, in the projection of machinery, where each cog-wheel entails so many constructive lines, that this alone would prevent the method coming into very general use.

The following method of projecting a circle may not be generally known, and though not quite correct, will be found sufficiently so in practice. It consists in laying down a three-centered curve, which will co-incide as nearly as possible with the true ellipse.



Let AB be the isometrical rhombus of the square circumscribing the circle; from each of the obtuse angles A and B let fall perpendiculars upon each of the opposite sides; these perpendiculars will bisect the sides, and intersecting in C and D, will give the centres of the two small arcs—A and B will be the centres of the larger ones.

Correspondence.

The Editor acknowledges with thanks, the receipt of the following Papers:—Lengths of Elliptic Arches—On Vaulted Roofs—Le Comptage Ambulant—Memo. on the Cavour Canal—Notes on Road Materials in India—Measurement of Irrigated Lands—Strains on Lattice Girders—Jamboosur and Broach Railway—Notes on Levelling.

To the Editor.

Dalhousie, 10*th Oct.*, 1865.

Sir,—In No. VIII. of the Professional Papers on Indian Engineering, of August last, in your article on the Ganges Canal Controversy, you say, "it began to be rumoured not very long ago, that many of the important masonry works of the Canal, were in a dangerous state In 1862 it was entirely closed for six months, to effect repairs, and though this was a solitary instance, it was known that the cost of ordinary annual repairs was very heavy, while it was reported that the quantity of water carried by the Canal was considerably under what had been originally intended."

As I was in Executive charge at that time, I think it is my duty to correct this mistake. The solitary instance referred to, was the dangerous state of the Mahmoodpoor Falls, which are 15 miles below Roorkee The state of these works was reported by me early in August 1862, and by orders of the late Superintendent General of Irrigation, the supply was then reduced.

From this time, till the 15th October, 1862, the Canal was running with a small supply, and on this date the Canal was closed for the annual repairs; after completing the repairs, as directed by the late Superintendent General, water was re-admitted into the Canal on the 25th November, 1862, but after it had been kept open for nearly two weeks, it was found that these Falls were again breaking up; consequently, the Canal was again closed on the 8th December, 1862, and a second set of repairs were completed, as directed by the late Superintendent General.

On the 22nd of the same month, water was again re-admitted, but the following morning it was found that the work had again failed, which necessitated the closing of the Canal a second time.

The third and last set of repairs, carried out on a different plan, were completed on the 10th January, 1863, when the Canal was again opened; and I am happy to observe, by Major Crofton's report, published in 1865, that they still stand.

You will observe, therefore, that there were three distinct sets of repairs; the first, occupying one month and ten days; the second, two weeks'; and the last, eighteen days; and taking them all together, the whole period the Canal was closed on this occasion only occupied about ten weeks, instead of six months.

The probable cause of this mistake, was that the *supply* was reduced for upwards of six months on this occasion, but as it is liable to cause the public to consider the Canal to be in a much worse state than it is, I beg you will kindly insert this letter in the next number of the Professional Papers.

I have, &c.,

T. LOGIN,

Late Supdt., Northern Division, Ganges Canal.

The Editor's attention was drawn to the mistake, above-mentioned, when some 50 copies of No. VIII. had been sent out. In all the other copies, the word *six* in the last line of page 203, was corrected with the pen to *three.* In explanation of the failure of the repairs above alluded to, it may be stated that the whole difficulty consisted in the water having to be turned on before the green masonry had had time to dry. A cement that can be laid *in* water, and which will harden *under* water, within 48 hours, is, so far as the Editor knows, still uninvented, and its utility in the repair of Canal works could scarcely be over-rated.—[ED.]

MY DEAR SIR,—You must of course be aware of the difficulty of getting good drinking water in many of our Himalayan Hill Stations; and how this difficulty has decided at once against the adoption of many sites in other respects admirably adapted for Sanitaria. Not only is water not easily obtained, but what is obtained is often very bad; and it is as well not to question the *bheestie* too closely, as to where it comes from.

Now the annual rain-fall in most of these Stations, is somewhere over 80 inches at least; and it seems to me to reflect little credit on our Indian Engineering, if we cannot manage to catch some of this tremendous fall, before it finds its way into the rivers below. Why should not large Tanks be built in suitable hollows as reservoirs of rain water? Cities at home are supplied in that way, and with the most satisfactory results. The size and form of such tanks would be a matter of simple calculation. Their construction in the hills where all building materials are at hand would be easy and inexpensive. To keep them pure they might be vaulted over, and the water filtered through gravel beds.

Can you, or any of your readers tell me if Tanks have ever had a fair trial, and if so how have they answered? I do not mean by *tanks*, the weedy ponds with masonry sides, which the Hindoo so admires, but properly constructed water reservoirs. For it seems to me, that by this simple expedient, we render ourselves independent of natural springs, in the choice of new hill Stations.

Perhaps some of our Bombay brethern could favor us with a history or description of the celebrated Aden tanks, which form the sole water supply of the garrison, and which I believe are only filled by the rain falling, not more than once every two or three years.

Believe me, &c.,